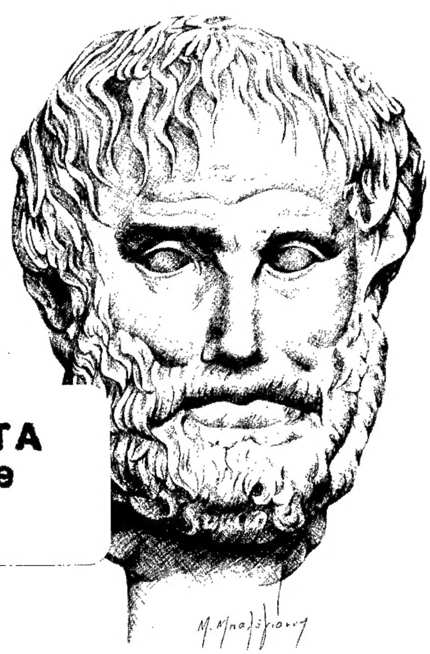
HELLENIC SOCIETY OF THEORETICAL
AND APPLIED MECHANICS (HSTAM)

ARISTOTLE UNIVERSITY
OF THESSALONIKI (AUTH)

6th NATIONAL CONGRESS OF MECHANICS

BOOK OF ABSTRACTS

EDITORS
E.C.AIFANTIS
A.N.KOUNADIS



THESSALONIKI,
JULY 19-21, 2001

Dedicated to the memory
of P.S.Theocaris

6th National Congress of Mechanics

Thessaloniki, 19-21 July 2001

Hellenic Society of Theoretical and Applied Mechanics (HSTAM)

Aristotle University of Thessaloniki (AUT)

BOOK OF ABSTRACTS

Editors: ***E. C. Aifantis*** **and** ***A. N. Kounadis***

Dedicated to the memory of
P. S. Theocaris

Thessaloniki 13 July 2001

Foreword

It was an honor that HSTAM (Hellenic Society of Theoretical and Applied Mechanics) assigned to the Laboratory of Mechanics of the General Department of AUT the responsibility of organizing the 6th National Congress of Mechanics in cooperation with the Department of Civil Engineering of AUT.

Special thanks to A. Kounadis and D. Beskos, president and secretary of HSTAM respectively, as well as to G. Manolis and D. Talaslidis who served as vice-chairmen of the organizing committee.

The Congress is dedicated to the memory of P. Theocaris whose influence on the Mechanics Community of Greece will remain for many years. My predecessor G. Lianis and A. Armenakas served as honorary chairmen of the Congress. My thanks go to them, as well as to the rest of the members of the organizing committees.

The Congress was organized during a very interesting period of substantial activity in the educational and scientific community in Greece. More than two months before the Congress, the University administration, at first, and the undergraduate student body as a whole, later, opposed certain educational proposals passed by the State, and daily university activities came to a standstill. This had a serious impact on the conference organization including the disruption of usual e-mail correspondence.

It was the determination of my graduate students G. Efremidis and P. Sapalidis, the help of F. Akintayo, K. Kosmidis, K. Kalaitzidou/S. Marras (currently at MTU/USA), the assistance of undergraduate students Th. Atmakidis and D. Dodou, as well as the encouragement of A. Kounadis, which helped me decide not to postpone the meeting. Special thanks go to George Efremidis who took upon himself the responsibility of completing the process of collecting the manuscripts, coordinating the e-mail correspondence, and other organizational details. My colleagues D. Beskos and G. Manolis were always available for consultation and advice. Many faculty of the General Department including its past and newly elected Chairman, as well as the Dean of Engineering were very supportive of this event.

The active participation of the travel agency Aethra, the publisher Giahoudi-Giapouli and the personal involvement of the owner of Philippion Hotel Helena Thoidou, who took the initiative to help with respective arrangements without requiring pre-payment, is worth mentioning. The financial support of the General Department, the College of Engineering, and the Research Committee of AUT, as well as of Democritus University of Thrace is

acknowledged. Also we acknowledge with thanks the financial support of the Ministry of Education, the Ministry of Culture and the Municipality of Thessaloniki. We also hope to have some financial support from the Ministry of Macedonia-Thrace and the Academy of Athens; but, at the time this foreword was composed, we had not yet received a definite decision from these governmental agencies, mainly due to difficulties in communication or decision-making during this unusual period of academic life.

Finally, sincere thanks go to all participants, especially those from abroad invited by HSTAM and myself or personally encouraged by me to attend. They all honored their commitment to participate despite the minimal information that could be distributed due to the aforementioned unforeseen circumstances. Many of the participants facilitated us greatly by pre-registering, thus enabling us to respond to initial financial obligations related to the Congress organization. It should be noted that as a result of the unusual circumstances mentioned above, it was not possible to activate a panel for a thorough review of the papers, which were accepted on the basis of their abstracts only.

Last, but not least, I would like to personally acknowledge the support and encouragement of the Minister of Yugoslavia, Professor Dragoslav Sumarac, for developing in Thessaloniki a Balkan Center of Mechanics with support from ERO and MTU with the participation of leading researchers of Mechanics and Materials of an international stature. In this respect, the sincere interest of Sam Sampath and the continuous help of my students I. Mastorakos, Avraam and Dimitris Konstantinidis in the organization of related research activities at AUT, as well as the scientific support of my student I. Tsagrakis, the research associate Mike Zaiser, and my physics colleague S. Logothetidis at AUT, are gratefully acknowledged.

Elias C. Aifantis
Chairman

6^{th} NATIONAL CONGRESS OF MECHANICS

Thessaloniki. 19 – 21 July, 2001

Hellenic Society of Theoretical and Applied Mechanics (HSTAM)
Aristotle University of Thessaloniki (AUT)

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Graduate students: G. Efremidis, P. Sapalidis, F. Akintayo, I. Mastorakos, K. Kosmidis, K. Kalaitzidou, S. Marras

Undergraduate students: Th. Atmakidis, D. Dodou

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PROGRAM * : Thursday July 19 **Chairman: E.C. Aifantis**

Registration: Wednesday 5^{00} pm – 9^{00} pm, Thursday 9^{00} am – 2^{00} pm, Friday 9^{00} am – 2^{00} pm Opening Remarks 8^{30} – 9^{00} am

Thursday July 19	SESSION A	SESSION B	SESSION C
$9^{00} - 10^{45}$ am	• **A. Acrivos** (US) • **C. Dafermos** (US) • **G. Maugin** (FR)	• **R. Schapery** (US) • **P. Ladeveze** (FR) • **D. Ruzic**, L. Markovic (YU)	• **N. Hajdin,** R. Mandic (YU) • **S. Kobayashi** (JP) • **W. Wunderlich**, R. Findeiß, H. Cramer (DE)
$10^{45} - 11^{00}$ am	Break	Break	Break
$11^{00} - 12^{05}$ pm	• **K. Valanis** (US) • **J. Kratochvil** (CZ)	• **D. Krajcinovic** (US) • **J. Lemaitre** (FR)	• **W. Sharpe** (US) • **C. Sciammarella**, F. Sciammarella (US)
$12^{05} - 2^{00}$ pm	LUNCH	LUNCH	LUNCH
$2^{00} - 3^{30}$ pm	• **E. Koronaki**, A. Boudouvis, et. al. (GR) • **T. Goudoulas**, E. Kastrinakis, S. Nychas (GR) • N. Malamataris, **V. Bontozoglou** et. al. (GR) • H. Mpimpas, **P. Anagnostopoulos** (GR) • C. Kouris, **J. Tsamopoulos** (GR) • N. Volakos, **R. Barber** (GR)	• **J. Katsikadelis**, G. Tsiatas (GR) • N. Hajdin, **B. Coric**, N. Markovic, D. Lucic (YU) • **C. Providakis**, S. Kourtakis (GR) • **C. Stiakakis**, Z. Agioutantis, G. Paschalis (GR) • **K. Spiliopoulos** (GR) • **A. Yiotis**, J. Katsikadelis (GR)	• **E. Gdoutos**, I. Daniel, K. Wang (GR) • **E. Gdoutos**, G. Papakaliatakis, I. Daniel (GR) • **M. Titsias**, D. Fotiadis, A. Likas (GR) • **I. Prassianakis**, P. Giokas (GR) • **S. Kourkoulis**, V. Kytopoulos (GR) • **N. Ninis**, S. Kourkoulis (GR)
$3^{30} - 4^{00}$ pm	Break	Break	Break
$4^{00} - 5^{30}$ pm	• M. Hadjinicolaou, **P. Vafeas** (GR) • **P. Anagnostopoulos**, A. Koutras, S. Seitanis (GR) • **T. Zervogiannis**, K. Giannakoglou, et. al. (GR) • **D. Smyrnaios**, N. Pelekasis, J. Tsamopoulos (GR) • **Y. Dimakopoulos**, J. Tsamopoulos (GR) • **V. Loukopoulos** (GR)	• G.Hatzigeorgiou, **M.Sfakianakis**, D.Beskos,et.al. (GR) • **C. Sophocleous**, K. Soldatos (CY) • J. Katsikadelis, **E. Sapountzakis** (GR) • I. Mademlis, S. Mamountsidis, **A. Avdelas** (GR) • G. Michaltsos, **D. Sophianopoulos** (GR) • **E. Zacharenakis**, G. Stavroulakis, et. al. (GR)	• **P. Gotsis** (C. Chamis, et. al.) (GR) • **D. Katerelos**, C. Galiotis (GR) • D. Varelis, **D. Saravanos** (GR) • D. Vlachos, Y. Pappas, **V. Kostopoulos** et. al. (GR) • **P. Kakavas** (GR) • **B. Christaras** (GR)
$5^{30} - 6^{00}$ pm	Break	Break	Break
$6^{00} - 7^{30}$ pm	• **G. Sideridis**, E. Kastrinakis, S. Nychas (GR) • **J. Demetriou**, D. Dimitriou (GR) • **J. Demetriou**, K. Pourliotis, P. Sarantos (GR) • **D. Margaris** (GR) • **K. Nanou-Giannarou**, J. Demetriou (GR) • **Th. Panidis** (GR)	• **M. Papadrakakis**, N. Lagaros (GR) • A. Elenas, **A. Liolios**, L. Vasiliadis, et. al. (GR) • **G. Manos**, A. Hatzigeorgiou, V. Soulis (GR) • N. Pnevmatikos, **C. Gantes** (GR) • **T. Salonikios** (GR) • **C. Dimou**, V. Koumousis (GR)	• **G. Anastassopoulos**, J. Lytras, S. Panteliou, et. al. (GR) • **A. Papachristidis**, G. Badaloukas, B. Badalouka (GR) • D. Zacharopoulos, E. Gdoutos, **D. Karalekas** (GR) • C. Koimtzoglou, **S. Goutianos**, C. Galiotis (GR) • **I. Chatjigeorgiou**, S. Mavrakos (GR) • G. Arampatzis, **C. Tzimopoulos** (GR)

PROGRAM * : Friday July 20 **Chairman: E.C. Aifantis**

Friday July 20	SESSION A	SESSION B	SESSION C
$9^{00}-10^{30}$ am	• **V. Tvergaard** I (DK) • **V. Tvergaard** II (DK) • **M. Marder**, E. Gerde I (US) • **M. Marder** II (US) • **G. Milton**, A. Movchan, S. Serkov I (US) • **G. Milton** II (US)	• **X. Markenscoff** (US) • **G. Dassios** (GR) • **J. Jaric**, K. Kishimoto, T. Wang, M. Omiya (YU) • **D. Lagoudas**, P. Entchev (US) • **V. Kalpakides**, G. Maugin (GR) • J. Staboulogiou, **E. Theotokoglou** (GR)	• **Y. Haddad** (CA) • S. Subramanian, **P. Sofronis** (US) • **P. Trovalusci**, R. Masiani (IT) • **P. Grammenoudis**, Ch. Tsakmakis (DE) • **D. Schick**, Ch. Tsakmakis (DE) • **N. Charalambakis** (GR)
$10^{30}-11^{00}$ am	**Break**	**Break**	**Break**
$11^{00}-12^{00}$ am	• **A. Varias**, A. Massih (SE) • **D. Bardzokas**, A. Zobnin (GR) • **D. Bardzokas**, M. Filshtinsky (GR) • **G. Stavroulakis**, H. Antes (GR)	• I. Vardoulakis, **G. Exadaktylos**, S. Kourkoulis (GR) • **E. Amanatidou**, N. Aravas (GR) • **G. Exadaktylos** (GR) • **S. Papargyri-Beskou**, K. Tsepoura, et. al. (GR)	• C. Karakostas, **G. Manolis** (GR) • **H. Georgiadis**, I. Vardoulakis, E. Velgaki (GR) • G. Lykotrafitis, **H. Georgiadis** (GR) • K. Dimitrakopoulou, **A. Mayraganis** (GR)
$12^{00}-2^{00}$ pm	**LUNCH**	**LUNCH**	**LUNCH**
$2^{00}-3^{30}$ pm	• V. Singh, X. Nie, P. Gupta, **E. Meletis** (US) • **C. Charitidis**, S. Logothetidis (GR) • **M. Pagitsas**, A. Diamantopoulou, D. Sazou (GR) • A.Kekatou, **N.Anifantis**, et. al. (GR) • **D. Briassoulis**, E. Schettini (GR) • J. Parthenios, **D. Bollas**, C. Galiotis et. al. (GR)	• X. Jiang, **A. Vakakis** (GR) • **T. Karakasidis**, I. Andreadis (GR) • **T. Karakasidis** (GR) • **D. Panayotounakos**, G. Exadaktylos, A. Vakakis (GR) • **C. Younis**, D. Panayotounakos (GR) • **V. Koumousis** (GR)	• **G. Voyiadjis**, R. Dorgan I (US) • **G. Voyiadjis** II (US) • **R. Desmorat** (FR) • **K.Tsepoura**, S.Papargyri-Beskou, D.Beskos et. al. (GR) • **E. Douka**, B. Polyzos, A. Trochidis (GR) • G. Bamnios, E. Douka, **A. Trochidis** (GR)
$3^{30}-4^{00}$ pm	**Break**	**Break**	**Break**
$4^{00}-5^{45}$ pm	• M. Zygomalas, **C. Baniotopoulos** et.al. (GR) • M. Kontoleon, **M. Betti** et. al. (GR) • **O. Panagouli**, E.S. Mistakidis (GR) • **E. Mistakidis**, N. Politis (GR) • **E. Mistakidis**, D. Georgiou (GR) • **T. Papaliangas** (GR) • **C. Demakos** (GR)	• **G. Tsaklidis**, K. Soldatos (GR) • **G. Foutsitzi**, A. Charalambopoulos, D. Fotiadis, et. al. (GR) • G. Kamvyssas, **F. Kariotou** (GR) • **E. Tzirtzilakis**, N. Kafoussias (GR) • **C. Dascalu**, D. Homentcovschi (RO) • **C. Dascalu**, D. Homentcovschi, et. al. (RO) • V. Kalpakides, **E. Agiasofitou** (GR)	• **A. Carpinteri**, B. Chiaia, P. Cornetti I (IT) • **A. Carpinteri** II (IT) • **G. Frantziskonis** (US) • **M-A. Abellan**, J-M. Bergheau, R. de Borst et. al. (NL) • J. Gilarranz, **O. Rediniotis** (US) • **V. Koukoulogiannis**, S. Ichtiaroglou (GR) • **T. Kalvouridis**, F. Psarros (GR)
$5^{45}-6^{00}$ pm	**Break**	**Break**	**Break**
$6^{00}-7^{30}$ pm	**SPECIAL SESSION** Current research directions and funding opportunities in US and EU : **G. Lianis** (GR), **K. Chong** (US), **T. Weber** (US), **D. Sumarac** (YU)		
$9^{00}-11^{00}$ pm	**BANQUET**		

6th NATIONAL CONGRESS ON MECHANICS **19-21 July 2001: AUT, Thessaloniki, HELLAS**

PROGRAM * : Saturday July 21 **Chairman: E.C. Aifantis**

Saturday July 21	SESSION A	SESSION B	SESSION C
$9^{00}-10^{30}$ am	• **R. de Borst**, H. Askes, M. Gutierrez, et. al. I (NL) • **R. de Borst** II (NL) • **H. Neuhaeuser**, F.Klose, H. Dierke, et. al. (DE) • A. Ziegenbein, F. Chmelik, **H. Neuhaeuser** (DE) • **T. Tsakalakos** I (US) • **T. Tsakalakos** II (US)	• **L. Kubin**, B. Devicre I (FR) • **L. Kubin** II (FR) • E. Aifantis, **A. Romanov**, et. al. I (RU) • A.Kolesnikova, **A.Romanov** et .al. II (RU) • D. Rodney, **A. Finel** I (FR) • **A. Finel** II (FR)	• A. Fernandes, **J. Pouget** I (FR) • **J. Pouget** II (FR) • **E. Meletlidou**, J. Pouget, G. Maugin, E. Aifantis (GR) • **T. Ioannidou**, J. Pouget, E. Aifantis (UK) • **P. Sutcliffe** (UK) • **A. Potapov**, V. Rodyushkin (RU)
$10^{30}-11^{00}$ am	Break	Break	Break
$11^{00}-12^{00}$ pm	• **K. Chihab**, H. Ait-Amokhtar (AL) • **D. Kugiumtzis**, E. C. Aifantis (UK) • **G. Stagika**, S. Ichtiaroglou, et. al. (GR) • **N.Tokiy**, T.Konstantinova, et. al. (UA)	• **I. Groma** (HU) • **S. Luding** (DE) • **M. Laetzel** (DE) • **N. Kioussis** (US)	• S. Lisina, **A. Potapov**, G. Utkin (RU) • **A. Potapov**, V. Kazhaev, S. Gromov (RU) • **M. Zaiser**, E. Aifantis (DE) • **M. Miguel** (ES)
$12^{00}-2^{00}$ pm	LUNCH	LUNCH	LUNCH
Special afternoon discussion / round table			

* ***This program was composed one month before the actual Congress takes place. Since that time several authors indicated that they will not be able to attend due to some unexpected circumstances. These include S. Kobayashi, K. Valanis, L. Kubin and a few others. Three additional authors, C. Christou, M. Muhammed, and G. Tsamasphyros have been added to the list of participants. Their abstracts are included in a special session entitled "Late Abstracts" along with X. Markenscoff's new abstract and four additional abstracts of graduate students and postdocs of the Laboratory of Mechanics and Materials of AUT. The final program, which will be distributed during registration, will reflect these changes. In this connection, it is pointed out that the last day of the Congress and the afternoon round table discussion on material instabilities will be re-constructed to better serve the goals of the post-conference event associated with the TMR Network annual meeting which will take place immediately after the Conference. Information on the TMR Network is attached.***

INFORMATION ON TMR NETWORK

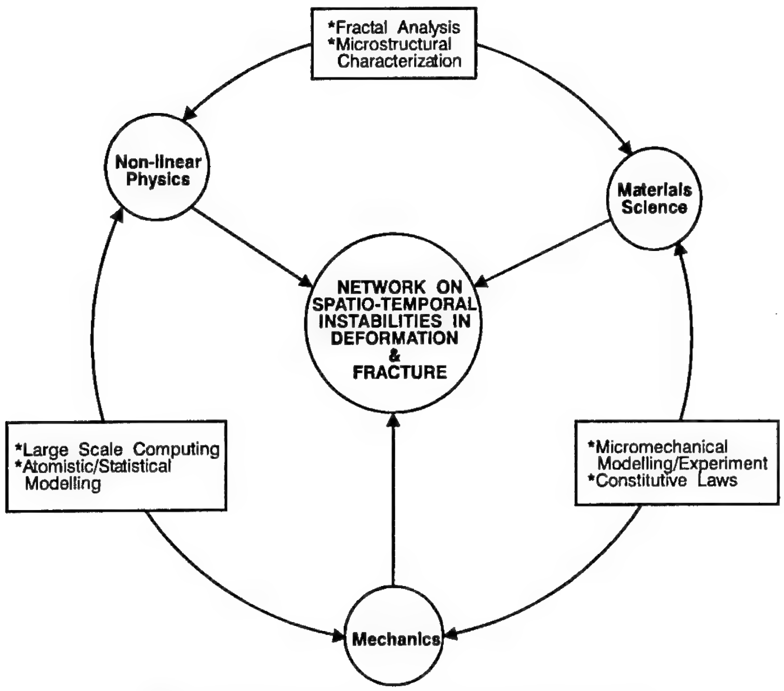

Figure 1. Scientific Interactions Between Different Thrusts

PARTNERS

*Aristotle University of Thessaloniki (AUT) *University of Cambridge (UC)
*Ecole Superieure Phys Chim Ind (ESPCI) *Universite Pierre et Marie Curie (UPMC)
*Technical University Braunschweig (TUB) *Polytecnico di Torino (PT)
*Technical University Delft (TUD)

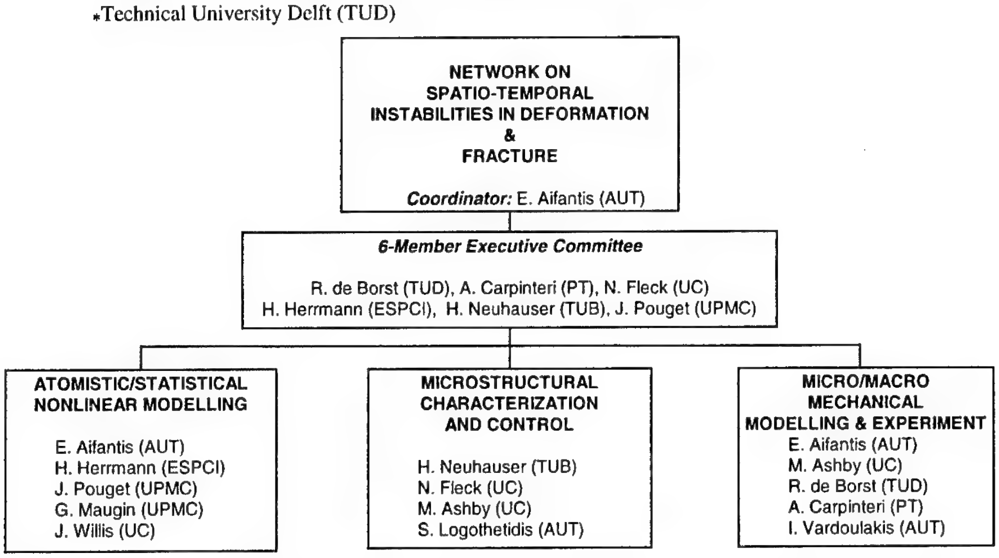

Figure 2. Network Organization and Principal Scientists Participation in Terms of Major Research Interests

6^{th} NATIONAL CONGRESS ON MECHANICS

19-21 July 2001, AUT –Polytechnic School, Thessaloniki, HELLAS

Chairman: E. C. Aifantis

PROGRAM

Thursday, July 19, 2001

8:30 – 9:00 **am** **Opening Remarks**

SESSION A

9:00 – 10:45	am	**Acrivos A.** (US) *The rheology of concentrated suspensions: Latest update on a theme by Albert Einstein*
		Dafermos C. (US) *Stability in nonlinear elastodynamics*
		Maugin G. (FR) *Thermomechanics of local structural rearrangements*
10:45 – 11:00	am	**BREAK**
11:00 – 12:05	pm	**Valanis K.** (US) *Quantum plasticity*
		Kratochvil J. (CZ) *On strain gradients in plasticity*
12:05 – 2:00	pm	**LUNCH**
2:00 - 3:30	pm	**Koronaki E.**, Theodoropoulos C., Boudouvis A., Kevrekidis I. (GR) *Enabling nonlinear computations through efficient time-stepping*
		Goudoulas T., Kastrinakis E., Nychas S. (GR) *Rheology of dense lignite-water suspensions; transition stresses on flow curves*
		Malamataris N., Vlachogiannis M., **Bontozoglou V.** (GR) *Computer simulation of the nonlinear evolution of inclined film flows*
		Mpimpas H., **Anagnostopoulos P.** (GR) *An improved coastal circulation model based on the characteristic-Galerkin technique*
		Kouris C., **Tsamopoulos J.** (GR) *On the effect of the relative viscosity of two fluids on the dynamics of axisymmetric core-annular flow in a tube*

		Volakos N., **Barber R.** (UK) *A comparison of the accuracy of various interpolation techniques for processing randomly scattered bathymetric data*
3:30 – 4:00	pm	**BREAK**
4:00 – 5:30	pm	Hadjinicolaou M., **Vafeas P.** (GR) *Interrelation between Stokes and Papkovich–Neuber eigenmodes for spheroidal Stokes flow*
		Anagnostopoulos P., Koutras A., Seitanis S. (GR) *Numerical study of oscillatory flow past pairs of cylinders at low Reynolds and Keulegan-Carpenter numbers*
		Zervogiannis T., Assouti V., Gagas K., Kaounis A., Giannakoglou K. (GR) *Inverse design of aerodynamic shapes using ant colony optimization*
		Smyrnaios D., Pelekasis N., Tsamopoulos J. (GR) *Stratified two-phase flow of vapour boundary layer-condensate film over a cylinder*
		Dimakopoulos Y., Tsamopoulos J. (GR) *Fluid displacement by air in a capillary tube*
		Loukopoulos V. (GR) *Flow between two rotating heated spheres*
5:30 – 6:00	pm	**BREAK**
6:00 – 7:30	pm	**Sideridis G.**, Kastrinakis E., Nychas S. (GR) *An experimental methodology for enhancing 2-d flow characteristics in a 3-d turbulent flow*
		Demetriou J., Dimitriou D. (GR) *Forces from jet flows on inclined discs*
		Demetriou J., Pourliotis K., Sarantos P. (GR) *Flow in open channels lined with different materials*
		Margaris D. (GR) *Airlift pump performance optimisation for deep-sea mining*
		Nanou-Giannarou K., Demetriou J. (GR) *Boundary shear in compound non-symmetrical channels*
		Panidis Th. (GR) *Use of height density function for the evaluation of measurements with a laser doppler anemometer*

Thursday, July 19, 2001

SESSION B

9:00 – 10:45	am	**Schapery R.** (US) *Damage models for viscoelastic composites*
		Ladevèze P. (FR) *Damage localisation and fracture in laminate composites*
		Ruzic D., Markovic L. (YU) *Cylindrical shells and their stability (choice of the deflection function and critical external radial pressure)*
10:45 – 11:00	am	**BREAK**
11:00 – 12:05	pm	**Krajcinovic D.** (US) *Essential structure of damage mechanics models*
		Lemaitre J. (FR) *Fatigue of materials and structures*
12:05 – 2:00	pm	**LUNCH**
2:00 - 3:30	pm	**Katsikadelis J.**, Tsiatas G. (GR) *Large deflection analysis of beams with variable stiffness. An analog equation solution*
		Hajdin N., **Coric B.**, Markovic N., Lucic D. (YU) *Yugoslav investigations concerning the patch loading on girders*
		Providakis C., Kourtakis S. (GR) *BEM solution of viscoplastic problems in metallic structures in the presence of temperature gradients*
		Stiakakis C., Agioutantis Z., Paschalis G. (GR) *Rock discontinuities in tunnel design: numerical simulation of the effects of filled and open joints*
		Spiliopoulos K. (GR) *On the numerical performance of a simplified method of analysis for creeping structures loaded cyclically*
		Yiotis A., Katsikadelis J. (GR) *Static and dynamic analysis of shell panels using the analog equation method*
3:30 – 4:00	pm	**BREAK**

4:00 – 5:30 pm

Hatzigeorgiou G., **Sfakianakis M.**, Theodorakopoulos D., Beskos D. (GR)
Numerical studies of anchors and rebars in concrete specimens by damage models

Sophocleous C., Soldatos K. (CY)
On the flexural modes of the Bickford beam theory

Katsikadelis J., **Sapountzakis E.** (GR)
A realistic estimation of the effective breadth of ribbed plates

Mademlis A., Marnountsidis S., **Avdelas A.** (GR)
On the study of tie plates in pin connections

Michaltsos G., **Sophianopoulos D.** (GR)
The effect of deck roughness in conjunction with other parameters on the dynamic response of steel highway bridges under vehicular loading

Zacharenakis E., Arvanitis K., Soldatos A., Stavroulakis G. (GR)
LQR and H^{∞} optimal structural control in aseismic design

5:30 – 6:00 pm **BREAK**

6:00 – 7:30 pm

Papadrakakis M., Lagaros N. (GR)
Reliability based optimization using neural networks

Elenas A., **Liolios A.**, Vasiliadis L., Sakellari M., Koliopoulos P. (GR)
A numerical estimation of the interrelation between acceleration parameters and damage indicators in earthquake engineering

Manos G., Hatzigeorgiou A., Soulis V. (GR)
Numerical investigation of the rocking response of ancient columns and colonnades under horizontal forces

Pnevmatikos N., **Gantes C.** (GR)
Elastoplastic response spectra for the design of structures subjected to exponential blast loading

Salonikios T. (GR)
Analytical estimation of total displacement's components of R/C shear walls with aspect ratio 1.0-1.5 subjected to seismic loads

Dimou C., Koumousis V. (GR)
Competition among genetic algorithms to improve robustness in optimization

Thursday, July 19, 2001

SESSION C

9:00 – 10:45	am	**Hajdin N.**, Mandic R. (YU) *Crushing of ship's bow structure during collision with bridge piers*
		Kobayashi S. (JP) *Synthesis of new phenolic polymers via enzymatic polymerization and their properties*
		Wunderlich W., Findeiβ R., Cramer H. (DE) *Adaptive finite element analysis of limit-load states in dry and saturated soils*
10:45 – 11:00	am	**BREAK**
11:00 – 12:05	pm	**Sharpe W.** (US) *Measurement of the mechanical properties of mems materials*
		Sciammarella C., Sciammarella F. (US) *Behavior of particle reinforced composites with soft matrices*
12:05 – 2:00	pm	**LUNCH**
2:00 - 3:30	pm	**Gdoutos E.**, Daniel I., Wag K. (GR) *Indentation failure of sandwich panels*
		Gdoutos E., Papakaliatakis G., Daniel I. (GR) *Indentation failure of a PVC cellular foam*
		Titsias M., Fotiadis D., Likas A. (GR) *Estimation of the concrete characteristics using pattern recognition methods*
		Prassianakis I., Giokas P. (GR) *Destructive and ultrasonic non-destructive testing of 28- day and 28-year old concrete*
		Kourkoulis S., Kytopoulos V. (GR) *Experimental quantification of crack tip parameters for particulate metal matrix composites*
		Ninis N., Kourkoulis S. (GR) *On selecting a compatible substitute for the Kenhcreae poros stone used in the Epidaurean Asklepieion*
3:30 – 4:00	pm	**BREAK**

4:00 – 5:30	pm	**Gotsis P.** (Chamis C., Minnetyan L., Abumeri G.) (GR) *Formal methods to design composite shells for robustness and affordability*
		Katerelos D., Galiotis C. (GR) *Stress concentration and matrix crack growth characteristics in composite laminates*
		Varelis D., **Saravanos D.** (GR) *Non-linear mechanics and buckling analysis of composite shells with embedded piezoelectric actuators and sensors*
		Vlachos D., Pappas Y., De Stefano R., **Kostopoulos V.** (GR) *A new design methodology for high temperature structural components made of continuous fiber ceramic composites exhibiting thermally induced anisotropic damage*
		Kakavas P. (GR) *Experimental and theoretical stress analysis of incompressible bonded elastomeric discs subjected to compression*
		Christaras B. (GR) *P-wave velocities for organizing the surface protection of stones. Example from Greece*
5:30 – 6:00	pm	**BREAK**
6:00 – 7:30	pm	**Anastassopoulos G.**, Lytras J., Sunaric M., Moulianitis V., Panteliou S., Bekos A., Kalinderis N., Hatzichristou D. (GR) *Optical device for prostate cancer detection*
		Papachristidis A., Badaloukas G., Badalouka B. (GR) *Experimental verification of shear wall modeling using finite element analysis*
		Zacharopoulos D., Gdoutos E., **Karalekas D.** (GR) *Failure of a composite with a broken fiber*
		Koimtzoglou C., **Goutianos S.**, Galiotis C. (GR) *Micromechanics of carbon fibre model composites under tensile, compressive and fatigue loading conditions*
		Chatjigeorgiou I., Mavrakos S. (GR) *Dynamic behavior of a hanged cable for deep water applications*
		Arampatzis G., **Tzimopoulos C.** (GR) *Experiments for the estimation of unsaturated hydraulic conductivity*

Friday, July 20, 2001

SESSION A

9:00 – 10:30 am		**Tvergaard V.** I (DK) *Use of cohesive zone models for elastic-plastic crack growth*
		Tvergaard V. II (DK) *Use of cohesive zone models for elastic-plastic crack growth*
		Marder M., Gerde E. I (US) *Continuum theory of self-healing interface cracks*
		Marder M. II (US) *Continuum theory of self-healing interface cracks*
		Milton G., Movchan A. , Serkov S. I (US) *Possible average fields in linear and non-linear composites*
		Milton G. II (US) *Possible average fields in linear and non-linear composites*
10:30 – 11:00 am		**BREAK**
11:00 – 12:00 pm		**Varias A.**, Massih A. (SE) *Material degradation and fracture in hydride forming metals*
		Bardzokas D., Zobnin A. (GR) *Problems of electromechanical fracture of dielectrics and piezoelectrics*
		Bardzokas D., Filshtinsky M. (GR) *Control of dynamic stress and fracture of piezoelectric bodies with cracks*
		Stavroulakis G. , Antes H. (GR) *Optimization and soft computing for inverse and crack identification*
12:00 – 2:00 pm		**LUNCH**
2:00 - 3:30 pm		Singh V., Nie X., Gupta P., **Meletis E.** (US) *Mechanical behavior of multilayered nanocomposite films*
		Charitidis C., Logothetidis S. (GR) *A comparative study of mechanical properties of state-of-the-art carbon based films*
		Pagitsas M., Diamantopoulou A., Sazou D. (GR) *The role of point defects on the growth and breakdown of metal passive films in electrolyte solutions*

Kekatou A., Sfakiotakis V., Katsareas D., **Anifantis N.** (GR)
Failure resistance to thermal shock of thermal barrier coatings using the finite element method

Briassoulis D., Schettini E. (GR)
Finite element analysis of the elastic mechanical behaviour of LDPE film

Parthenios J., Psarras G., **Bollas D.**, Galiotis C. (GR)
Adaptive composites incorporating shape memory alloy wires; recording the internal stress by laser raman spectroscopy

3:30 – 4:00 pm **BREAK**

4:00 – 5:45 pm Zygomalas M., Kontoleon M., **Baniotopoulos C.** (GR)
A hemivariational inequality approach to the resistance of aluminium riveted connections

Kontoleon M., Baniotopoulos C., **Betti M.**, Borri C. (GR)
Analysis of convex energy structural systems under stochastic loading

Panagouli O., Mistakidis E.S. (GR)
Friction evolution in fractal interfaces

Mistakidis E., Politis N. (GR)
Numerical study of the F.E. mesh dependency in nonconvex-nonsmooth engineering problems

Mistakidis E., Georgiou D. (GR)
Fuzzy sets in engineering analysis and design

Papaliangas T. (GR)
Contact mechanics of geomechanical interfaces separated by a weak material

Demakos C. (GR)
Bending and warping in fiber reinforced rectangular beams

5:45 – 6:00 pm **BREAK**

Friday, July 20, 2001

SESSION B

9:00 – 10:30	am	**Markenscoff X.** (US) *The Cosserat spectrum theory and applications in solid and fluid mechanics*
		Dassios G. (GR) *On the potential representations for polyadics and anisotropic media*
		Jaric J., Kishimoto K., Wang T., Omiya M. (YU) *The application of Noether's theorem to non-linear anisotropic elastic materials*
		Lagoudas D., Entchev P. (US) *Micromechanical modeling of the behavior of porous shape memory alloys*
		Kalpakides V., Maugin G. (GR) *Variational formulation and material balance laws of dissipationless thermoelasticity*
		Staboulоglou J., **Theotokoglou E.** (GR) *The infinite isotropic wedge under linearly distributed loading*
10:30 – 11:00	am	**BREAK**
11:00 – 12:00	pm	Vardoulakis I., **Exadaktylos G.**, Kourkoulis S. (GR) *Size effect on failure load of marble beams under three point bending*
		Amanatidou E., Aravas N. (GR) *Finite element techniques for strain-gradient elasticity problems*
		Exadaktylos G. (GR) *The elastic punch problem revisited*
		Papargyri-Beskou S., Tsepoura K., Polyzos D., Beskos D. (GR) *Gradient elastic Bernoulli-Euler beams in bending and buckling*
12:00 – 2:00	pm	**LUNCH**
2:00 - 3:30	pm	Jiang X., **Vakakis A.** (GR) *Dual mode vibration isolation based on nonlinear mode localization*
		Karakasidis T., Andreadis I. (GR) *A fractional Brownian motion model for timeseries produced by constant energy molecular dynamics simulations*

Karakasidis T. (GR)
Vibrational properties of a $\Sigma 5(310)[001]$ NiO grain boundary studied by molecular dynamics simulation

Panayotounakos D., Exadaktylos G., Vakakis A. (GR)
Analytical solution of the nonlinear damped Duffing oscillator

Younis C., Panayotounakos D. (GR)
Nonlinear effects on the elastic stability of a column-footing system on elastic base

Koumoussis V. (GR)
Non-linear dynamic behaviour of base isolators

3:30 – 4:00 pm **BREAK**

4:00 – 5:45 pm **Tsaklidis G.,** Soldatos K. (GR)
The continuous time homogeneous Markov system with fixed size as a linear elastic continuum

Foutsitzi G., Charalambopoulos A., Fotiadis D., Massalas C. (GR)
Study of the dynamic characteristics during callus formation

Kamvyssas G., **Kariotou F.** (GR)
On the electroencephalography (EEG) problem for the ellipsoidal brain model

Tzirtzilakis E., Kafoussias N. (GR)
Mathematical models for biomagnetic fluid flow and applications

Dascalu C., Homentcovschi D. (RO)
Lamellar inhomogeneities in piezoelectric solids

Dascalu C., Homentcovschi D., KalpakidesV., Hadjigeorgiou E. (RO)
On a new crack model for piezoelectric solids

Kalpakides V., **Agiasofitou E.** (GR)
Thermo-electro-elastic material momentum equation

5:45– 6:00 pm **BREAK**

Friday, July 20, 2001

SESSION C

9:00 – 10:30	am	**Haddad Y.** (CA) *On the stochastic micromechanical theory of discrete material systems*
		Subramanian S., **Sofronis P.** (US) *A constitutive law for powder compaction*
		Trovalusci P., Masiani R. (IT) *Continuum micropolar modelling of discontinuous masonry-like systems*
		Grammenoudis P., Tsakmakis Ch. (DE) *Some aspects of a micropolar plasticity theory*
		Schick D., Tsakmakis Ch. (DE) *Description of plastic anisotropy at large deformations*
		Charalambakis N. (GR) *«Cold» work and stability in softened materials*
10:30 – 11:00	am	**BREAK**
11:00 – 12:00	pm	Karakostas C., **Manolis G.** (GR) *Some basic solutions to dynamic problems in random media*
		Georgiadis H., Vardoulakis I., Velgaki E. (GR) *Analysis of Rayleigh waves in microstructured solids by dipolar gradient elasticity*
		Lykotrafitis G., **Georgiadis H.** (GR) *The 3-D thermo-elastodynamic problem of moving loads in a half-space*
		Dimitrakopoulou K., **Mavraganis A.** (GR) *The attitude motion of a carrier-rotor system with almost symmetric inertia ellipsoid, under body-fixed torques*
12:00 – 2:00	pm	**LUNCH**
2:00 - 3:30	pm	**Voyiadjis G.**, Dorgan R. I (US) *Gradient anisotropic damage in MMCS for bridging length scales between macroscopic response and microstructure*
		Voyiadjis G. II (US) *Gradient anisotropic damage in MMCS for bridging length scales between macroscopic response and microstructure*
		Desmorat R. (FR) *Two scale damage model for fatigue representation of gradient effects*

Tsepoura K., Papargyri-Beskou S., Polyzos D., Beskos D. (GR)
Gradient elastic bars under uniaxial static or dynamic load

Douka E., Polyzos B., Trochidis A. (GR)
Evolution of persistent slip bands in fatigued metals

Bamnios G., Douka E., **Trochidis A.** (GR)
Crack identification in beam structures

3:30 – 4:00 pm **BREAK**

4:00 – 5:45 pm **Carpinteri A.**, Chiaia B., Cornetti P. I (IT)
Fractals and fractional calculus in solid mechanics

Carpinteri A. II (IT)
Fractals and fractional calculus in solid mechanics

Frantziskonis G. (US)
Characterization of materials with pores and inclusions at diverse scales

Abellan M-A., Bergheau J-M., Huyghe J., de Borst R. (NL)
Semi-analytical solution for a 1-d simplified THMPC modelling of a non-saturated soil

Gilarranz J., **Rediniotis O.** (US)
Compact, high-power, synthetic jet actuators for flow separation control

Koukouloyiannis V., Ichtiaroglou S. (GR)
Localized periodic motions in systems of coupled oscillators

Kalvouridis T., Psarros F. (GR)
Effect of the parameters on the dynamic behavior of a small particle in an annular distribution of n- bodies

5:45 – 6:00 pm **BREAK**

Friday, July 20, 2001

SPECIAL SESSION

6:00 – 7:30 pm Current research directions and funding opportunities in US and EU

Lianis G. (GR)
Fundamendal vs. Applied Research

Chong K., Davis D. (US)
Research and challenges of engineering mechanics and materials in the twenty first century

Weber T. (US)
Materials research at the National Science Foundation and the NSF nanoscale science and engineering initiative

Sumarac D. (YU)
Damage mechanics application on repair of destroyed structures: Impact on Yugoslavia's reconstruction

Saturday, July 21, 2001

SESSION A

9:00 – 10:30	am	**de Borst R.**, Askes H., Gutierrez M., Wells G. I (NL) *Computational aspects of material instabilities*
		de Borst R. II (NL) *Computational aspects of material instabilities*
		Neuhäuser H., Klose F., Dierke H., Ziegenbein A., Nortmann A. (DE) *Experimental studies of plastic instabilities in solid solutions*
		Ziegenbein A., Chmelik F., **Neuhäuser H.** (DE) *Combined measurements of acoustic emission and laser extensometry during Portevin-Le Chatelier deformation in an Al-Mg alloy*
		Tsakalakos T. I (US) *Tomograhic profiling of internal stresses*
		Tsakalakos T. II (US) *Tomograhic profiling of internal stresses*
10:30 – 11:00	am	**BREAK**
11:00 – 12:00	pm	**Chihab K.**, Ait-Amokhtar H. (AL) *Serrated yielding and nonuniform plastic deformation of Portevin–Le Chatelier effect in commercial Al-Mg alloys*
		Kugiumtzis D., Aifantis E. (UK) *Time series analysis and the deterministic structure of the PLC effect*
		Stagika G., Ichtiaroglou S., Aifantis E., Groma I. (GR) *Some dynamical system considerations for dislocations*
		Tokiy N., Konstantinova T., Varyukhin V., Tokiy A. (UA) *The dislocation model of local bend*
12:00 – 2:00	pm	**LUNCH**

SPECIAL AFTERNOON DISCUSSION / ROUND TABLE

Saturday, July 21, 2001

SESSION B

9:00 – 10:30	am	**Kubin L.**, Devincre B. I (FR) *Multiscale plasticity: linking discrete and continuum approaches*
		Kubin L. II (FR) *Multiscale plasticity: linking discrete and continuum approaches*
		Aifantis E., **Romanov A.**, Seefeldt M., Klimanek P. I (RU) *Disclination-dislocation reaction kinetics in application to deformation phenomena in solids*
		Kolesnikova A., Klemm V., Klimanek P., **Romanov A.** II (RU) *Elasticity of wedge disclinations in thin plates: application to electron microsopy study of defect structure in deformed crystals*
		Rodney D., **Finel A.** I (FR) *Phase field methods and dislocations*
		Finel A. II (FR) *Phase field methods and dislocations*
10:30 – 11:00	am	**BREAK**
11:00 – 12:00	pm	**Groma I.** (HU) *Statistical properties of dislocation assemblies in view of linking different scales*
		Luding S. (DE) *Micro-macro transition for cohesive granular media (macroscopic material behavior from microscopic simulations)*
		Laetzel M. (DE) *Macroscopic material properties from quasi-static, "microscopic" discrete element simulations (macroscopic material behavior from microscopic simulations)*
		Kioussis. N. (US) *Linking atomistic and continuum approaches for studies of dislocation core properties in FCC metals and the effect of chemistry*
12:00 – 2:00	pm	**LUNCH**

SPECIAL AFTERNOON DISCUSSION / ROUND TABLE

Saturday, July 21, 2001

SESSION C

9:00 – 10:30 am	Fernandes A., **Pouget J.** I (FR) *Modelling of laminated composite structures with piezoelectric layers*
	Pouget J. II (FR) *Modelling of laminated composite structures with piezoelectric layers*
	Meletlidou E., Pouget J., Maugin G., Aifantis E. (GR) *Invariant relations in a Boussinesq type equation*
	Ioannidou T., Pouget J., Aifantis E. (UK) *Kink dynamics in a long-range interaction model*
	Sutcliffe P. (UK) *Magnetic solitons*
	Potapov A., Rodyushkin V. (RU) *The propagation of strain waves in materials with microstucture*
10:30 – 11:00 am	**BREAK**
11:00 – 12:00 pm	Lisina S., **Potapov A.**, Utkin G. (RU) *Governing equations and balance laws for micropolar continuum*
	Potapov A., Kazhaev V., Gromov S. (RU) *Spliting up of multistable solitons in solids*
	Zaiser M., Aifantis E. (DE) *Modeling the crushing of a cellular material*
	Miguel. M. (ES) *Statistical physics aspects of plasticity*
12:00 – 2:00 pm	**LUNCH**

SPECIAL AFTERNOON DISCUSSION / ROUND TABLE

Thursday 19 July

THE RHEOLOGY OF CONCENTRATED SUSPENSIONS: LATEST UPDATE ON A THEME BY ALBERT EINSTEIN

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ABSTRACT

The viscous flow of concentrated suspensions gives rise to a number of fascinating phenomena, many of which are due to the shear-induced particle migration from regions of high concentration to low and from regions of high shear to low. Some of these phenomena will be illustrated and quantitative explanations will be offered for the experimental observations. Nevertheless, there still exist several puzzling and hitherto unexplained experimental results, some of them quite recent, which will be presented and discussed

STABILITY IN NONLINEAR ELASTODYNAMICS

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ABSTRACT

The lecture will point out the obstacles encountered in the theory of elastodynamic stability, posed by the lack of lobal convexity in the strain energy function, and will discuss how this difficulty may be resolved by exploiting the special geometric structure of the equations.

THERMOMECHANICS OF LOCAL STRUCTURAL REARRANGEMENTS

Gérard A. Maugin

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ABSTRACT

Local structural rearrangements are responsible for many of the macroscopically observed irreversible behaviors of solid-like materials. Along this line of thought we find the manifestations of anelasticity and akin phenomena (plasticity, viscoplasticity, damage, phase transitions, growth). All these take place directly on the material manifold. That is, their arena and that of the associated driving forces, also called *configurational forces* , or *material forces* in modern continuum mechanics, require a general setting that emphasizes this material peculiarity. Such a setting, mainly geometrical and thermodynamical, was developped within the last ten years by the author and co-workers via the inclusive notions of uniformity maps, inhomogeneity maps, and material transplants. Generalized material forces appear then as those " forces " which are associated by duality to the displacement or motion of whatever may be considered a *defect* or *material inhomogeneity* in a continuum field theory. Conceptually simple examples of such " defects " are cracks in materials science, propagating fronts in phase-transition problems, shock waves in continuum mechanics, and more generally all manifestations, smooth or abrupt, of changes in material properties. In such a framework, the essential kinetic argument is the so-called Eshelby material stress. Configurational forces built from it acquire a true physical meaning only in so far as the associated expended power is none other than a *dissipation* ; accordingly, these configurational forces are essentially used to formulate *criteria of progress* of "defects" or "inhomogeneities" in accordance with the second law of thermodynamics. Various examples are given here in this unified view.

QUANTUM PLASTICITY

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ABSTRACT

This paper was initially motivated by a need to provide a theoretical basis, within the framework of gradient thermodynamics, for the unstable behavior of metals at a phenomenological scale. It is observed that when large material domains in reference to their atomic dimensions – such as soft aluminum specimens in tension or in torsion – are deforming under slow load control, they do so uniformly and continuously, except at specific values of the applied traction, when they deform spontaneously, from their present geometric configuration to a different one, at constant traction. Simultaneously new periodic patterns appear on the surface of the specimens. Such observations have been reported beginning with the work of Portevin and Chatelier and since then by other experimentalists. Of these, Lubahn, Dillon and Sharpe and their work will be given special attention.

In course of the analysis we observed that this kind of behavior is reminiscent of the quantum behavior of atomic systems. We asked, therefore, the question whether these instabilities may be predicted, or at a minimum depicted, by a differential equation similar in form to the Schrodinger Equation for the quantum behavior of atomic systems.

The purpose of this work then is to derive a partial differential equation, henceforth referred to as the Quantum Instability Equation, within the scope of an inelastic gradient theory developed previously by the Author and to show that in the manner of the quantum theory the said equation depicts the observed discrete occurrences of the material instabilities. Further, it is to show that the theoretical values of the tractions at points of instability are in close agreement with their experimental counterparts.

It is of interest that within a multiplicative constant, these theoretical values are the eigen-values of the solutions of the Quantum Instability Equation and the eigen-solutions are periodic (or quasi-periodic) modes of inelastic deformation (depending on the geometry of the domain) such as the ones observed in experiment.

There are striking parallels between the unstable behavior of metals at the phenomenological scale and the time-independent quantum behavior of atomic systems at the atomic scale. These will be illustrated in the course of the lecture.

ON STRAIN GRADIENTS IN PLASTICITY

Jan Kratochvil

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ABSTRACT

The classical theory of plasticity predicts no size effects and fails to describe localization of plastic strain in a realistic way. However, several observed plasticity phenomena display a size effect whereby the smaller is the size the stronger is the response. In describing strain localization the classical theory predicts infinitely thin shear band lamellae and finite element analysis of localized modes of deformation are mesh dependent.

A standard way of extending plasticity to get rid of the unwanted features mentioned above is to enrich the model of elasto-plastic continuum by introducing higher strain gradients, or additional degrees of freedom of the Cosserat type directors). Customary, the enriched structure of the advanced plasticity theories is related to the density of dislocations arising due to local plastic deformation inhomogeneities. It is supposed that the field of plastic strain gradients is caused by geometrically necessary dislocations trapped in a volume element of a certain characteristic size that is usually introduced as a model type or curve fitting parameter without a relation to measurable quantities.

In a detailed analysis of the macroscopic shear bands it is demonstrated that the above mentioned framework can be misleading. Surface observations reveal that a macroshear band on the sample scale is composed of a set of parallel regularly spaced microshear bands. A macro band propagates across the sample by increasing in length and thickness through activation of new micro bands, whereas the former ones become inactive. The characteristic distance between micro bands is a base for introducing of physically meaningful higher gradients. The distance is controlled by hardening within the micro bands and a notch effect at the surface caused by micro bands. Another set of higher gradients is vital for dislocation pattern development which govern strain hardening properties of materials. In both cases the introduced gradients have nothing to do with geometrically necessary dislocations popular in many current versions of gradient theories of plasticity.

ENABLING NONLINEAR COMPUTATIONS THROUGH EFFICIENT TIME-STEPPING

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ABSTRACT

An often large system of nonlinear ODEs (or DAEs), results from the discretization of time-dependent, nonlinear PDEs. Equilibrium solutions of the original PDEs can be obtained by integrating the resulting ODEs (or DAEs) to steady state. This approach, when combined with appropriate continuation algorithms, constitutes a systematic path towards revealing the effects of nonlinearities. The efficacy of this approach is inextricably linked to the numerical time integration scheme.

Time integration can become very slow and eventually fail to converge at certain parameter values that are close to singularities. The Recursive Projection Method (RPM), proposed by Shroff and Keller[1], is implemented in this study in order to enhance the rate and also guarantee convergence. Two time integration schemes are employed, in combination with the Galerkin/finite element method for spatial discretization, in order to find steady states of the Bratu problem in one dimension: a) the forward Euler (FE) scheme and b) an implicit-explicit one step scheme (IE) proposed by Akrivis et al.[2]

The effect of the size of the time steps used is demonstrated here, emphasizing issues of eigenvalue spectra and performance of the RPM for both time-steppers.

The numerical investigation shows that regardless of the size of the time step, the RPM enhanced the convergence rate of both schemes to the corresponding steady states and even allowed the computation of unstable solutions. In addition, the most dangerous eigenvalues of the time integration schemes were detected with significant accuracy with the help of the RPM. As far as the IE scheme is concerned, it appears that the performance of the RPM, either as a means of achieving faster convergence or as a way of determining the most dangerous eigenvalues, is not influenced at all by the fineness of the spatial discretization, in contrast to the FE scheme[3].

References:

[1] Shroff, G. M. and Keller, H. B., *SIAM J. Numer. Anal.*, Vol 30, No. 4, pp. 1099-1120, 1993. [2] Akrivis, G., Crouzeix, M., Makridakis, C., *Math. Comp.*, 67, pp. 457-477, 1998. [3] Davidson, B. D., *SIAM J. Numer. Anal.*, Vol. 34, No. 5, pp 2008-2027, 1997.

RHEOLOGY OF DENSE LIGNITE-WATER SUSPENSIONS; TRANSITION STRESSES ON FLOW CURVES

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ABSTRACT

The objective in Lignite-Water Slurries (LWS) technology is the preparation of a relatively stable dense suspension of coal in aqueous medium having the higher possible solid loading with acceptable rheological behavior. It is common that LWS are characterised by broad particle size distributions and their rheological behavior is non-Newtonian affected by a number of parameters. For example, the relative viscosity, η_r, or the appearance of a yield stress depends on the ratio of the solids volume fraction, ϕ, and the maximum achieved solids volume fraction, ϕ_m. LWS with bimodal particle size distribution from 1 μm to 300 μm was prepared with a solids concentration of 46.3 wt%. The pH of the produced slurry was in the range of 6.5 to 6.9. Aspects of dense LWS rheology were investigated using a controlled stress rheometer, Carri-Med CLS100, with parallel plate geometry. Measurements of the flow curves were carried out for various ascending times, shear rate regions and testing times. Various characteristic viscosities during a flow curve testing were defined and studied with respect to a measurement procedure. In the ascending part of the flow curves a transition point was observed, which was characterized by a local maximum stress, σ_{tr}. The variation of the transition point with respect to solids loading, shear stress region and testing time was investigated. Moreover, the position of the transition point, which was identified in the ascending part of the flow curves, was further studied. It was found that the shear stress at which the transition occurs, depends upon solids concentration, total time of testing and shear stress range. It was also found that the applied rate of shear stress, under which the slurry is tested is an important parameter of its rheological behavior. In an attempt to interpret the rheological data, structural aspects of the LWS were considered.

COMPUTER SIMULATION OF THE NONLINEAR EVOLUTION OF INCLINED FILM FLOWS

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ABSTRACT

Wave evolution on an inclined or vertical falling film is an open-flow, convective instability, which has attracted the attention of many investigators. The problem is very old and continued interest stems from a host of engineering applications in industrial processes. The spatio-temporal evolution of the instability has been studied experimentally by imposition of disturbances of specific frequency. Recent results (Liu & Gollub, 1994) indicate that high-frequency disturbances lead to saturated periodic waves, whereas low-frequency disturbances result in solitary waves consisting of a major hump preceded by front-running bow waves.

In the present work, we report on a direct numerical simulation of film flow based on the Galerkin finite-element formulation. The novelty of the approach is that -rather than imposing periodic boundary conditions (Salamon et al. 1994)- we integrate the time-dependent equations as an initial-value problem. To produce an efficient algorithm, the outflow boundary condition is treated by a technique originally proposed by Malamataris & Papanastasiou (1991). Thus, the spatio-temporal evolution leading downstream to the highly nonlinear stationary forms is fully recovered. In addition, the computation is ideally suited for comparison with experiments.

The simulation is validated by numerically reproducing the linear stability analysis results. A small-amplitude sinusoidal disturbance of specific frequency is introduced at the inlet film thickness and its initial development is found to be exponential with fetch. The computed phase velocity and linear growth rate are in agreement with linear stability theory (Anshus & Goren, 1966) as well as with precise measurements (Liu et al., 1993).

Nonlinear evolution is computed by imposing higher amplitude inlet disturbances, because it is found that, in this way, attainment of the final stationary form occurs over a shorter fetch. Disturbances of 1.5, 4.5 and 7 Hz are imposed on a film flowing over a wall with inclination of 6.4° with Re=29 and We=35 (both based on the free surface velocity). The high-frequency disturbance results in saturated periodic waves, the low-frequency in well-separated solitary waves and the intermediate frequency produces multi-peaked quasi-periodic waves. The computed spatio-temporal evolution is in quantitative agreement with experimental results reported under the exact same conditions by Liu & Gollub (1994).

Keywords: Finite elements, Convective instability, Linear stability, Periodic waves, Solitary waves

References:

[1] Anshus, B. E. & Goren, S. L., Alche J. **12**, 1004-1008 (1966)
[2] Liu, J., Paul & J. D., Gollub, J. P. *J. Fluid Mech.* **250**, 69-101 (1993).
[3] Liu, J. & Gollub, J. P. *Phys. Fluids* **6**, 1702-1712 (1994).
[4] Malamataris, N. T. & Papanastasiou, T. C. *Ind. Engng. Chem. Res.* **30**, 2210-2219 (1991).
[5] Salamon, T. R., Armstrong, R. C. & Brown, R. A. *Phys. Fluids* **6**, 2202-2220 (1994).

AN IMPROVED COASTAL CIRCULATION MODEL BASED ON THE CHARACTERISTIC-GALERKIN TECHNIQUE

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ABSTRACT

The derivation of water circulation in a coastal area from the solution of shallow water equations is one of the most frequent problems in the fields of coastal and environmental engineering. Finite element methods are well-established for the solution of shallow water equations, because of their ability to model irregular geometries like complex coastlines, islands and strongly varying bathymetry. However, there exist various problems associated with the numerical solution of these equations, such as the appearance of the 2-Δx waves, which should be reduced. These problems have motivated researchers to the development of improved numerical schemes. Moreover, the correct modeling of turbulence in this kind of geophysical flows is very important for the accuracy of the results.

In the present study the numerical solution of the shallow water equations is attempted, using the characteristic-Galerkin technique for the temporal discretisation. The wind shear is the forcing term of the phenomenon. The comparison of the new algorithm with the standard Galerkin method shows that the characteristic-Galerkin model improves considerably the results, by reducing greatly the 2-Δx waves, even for very small values of turbulent viscosity coefficients. Next, the Smagorinsky model was applied, for the improvement of turbulence modeling, compared with the constant eddy viscosity coefficients. For all cases the results are presented in diagrams, depicting the stream velocity and the water depth.

ON THE EFFECT OF THE RELATIVE VISCOSITY OF TWO FLUIDS ON THE DYNAMICS OF AXISYMMETRIC CORE-ANNULAR FLOW IN A TUBE

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ABSTRACT

Nonlinear dynamics of the concentric, two-phase flow of two immiscible fluids in a circular tube is studied. A pseudo-spectral numerical method is coupled with an implicit second order time-integration scheme to solve the complete mass and momentum conservation equations as an initial value problem. The simulations originate with the analytical solution for the pressure driven, steady, Core-Annular Flow (CAF) in a tube. The volume fraction of each fluid in the tube and the total flow rate of both fluids are imposed. Furthermore, the length of the tube is taken to be as long as computationally possible in order to allow for multiple waves of different lengths to develop and interact as reported in the experiments and in earlier, weakly nonlinear analyses.

When the viscosity ratio of the fluid in the annulus to that in the core of the tube, μ, is smaller than unity we performed simulations of CAF for conditions under which the reported flow charts indicate that both phases retain their integrity but the original steady flow is unstable. Then, it was found that indeed traveling waves develop with slightly sharper crests (pointing towards the annular fluid) than troughs, the so-called "bamboo waves". Despite the uneven interface, the flow in the core fluid closely resembles Poiseuille flow, but in the annular fluid small recirculation zones develop at the level of each crest. As the Reynolds number or the flow rate of the core fluid increase, the average wavelength and the amplitude of these waves decrease. Their specific values for each examined case are in closer agreement with the experiments than in earlier theoretical reports. For large values of interfacial tension, waves with even different wavelength move with the same velocity, whereas for small values, they attain variable velocities and approach or repel each other but no wave merging or splitting is observed.

When μ is larger than or equal to unity, the perfect Core-Annular Flow (CAF) is linearly unstable and it is necessary to keep the ratio of the thickness of the annulus to the radius of the tube small so that the solutions remain uniformly bounded. Quite regular wave patterns are predicted in the first two cases, whereas multiple unstable modes grow and remain even after saturation of the instability in the last case. The resulting waves generally travel in the same direction and faster than the interface, except for the case with μ=1 for which they are stationary with respect to the unperturbed interface. Depending on parameter values, waves move with the same velocity or interact with each other exchanging their amplitudes or merge and split giving rise to either chaotic or organized solutions. For fluids of equal viscosities and densities (μ=ρ=1) and for Reynolds 0.0275 and inverse Weber number, W=145.4, small amplitude waves are predicted. The increase of μ by almost two orders of magnitude does not

affect their amplitudes, but increases their temporal period linearly. Varying W by more than three orders of magnitude increases their amplitudes proportionately, while their period increases with the logarithm of W. Similar to that is the effect of increasing Re. The present analysis confirms and extends results based on long wave expansions, which lead to the Kuramoto-Sivashinsky equation and modifications of it.

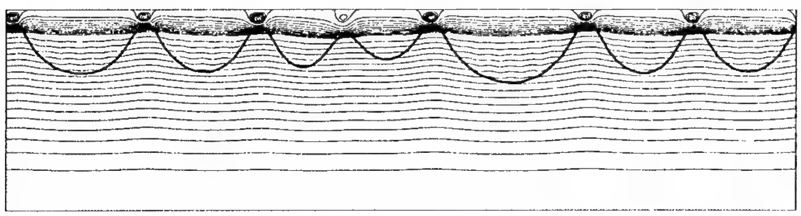

Figure: Streamlines in a reference frame fixed with the wall as well as the fully developed bamboo wave form.

Keywords – Core-Annular Flow – Interfacial waves – Dynamic Simulations.

References:

[1] Kouris, Ch. & Tsamopoulos, J. (2000) "Dynamics of axisymmetric core-annular flow. I. The more viscous fluid in the core, bamboo waves", submitted for publication to *Phys. Fluids*.

[2] Kouris, Ch. & Tsamopoulos, J. (2000) "Dynamics of axisymmetric core-annular flow. II. The less viscous fluid in the core, saw tooth waves", submitted for publication to *Phys. Fluids*.

A COMPARISON OF THE ACCURACY OF VARIOUS INTERPOLATION TECHNIQUES FOR PROCESSING RANDOMLY SCATTERED BATHYMETRIC DATA

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ABSTRACT

As part of the development of a hydrodynamic model of a natural water body, such as an estuary or coastal sea, spot depths must be assigned to all nodes of the computational grid. In most cases, the available depth data (or bathymetry) obtained from sea-charts will vary in spatial resolution between well surveyed shipping channels and sparsely surveyed surrounding shallows. Often, however, the flow behaviour in the shallow near-shore region has a significant effect on the overall hydrodynamics of the flow domain. It is therefore important that the method of interpolation from the measured bathymetry onto the nodes of the hydrodynamic mesh is as accurate as possible and uses the available depth data to best effect. The choice of an inappropriate depth interpolation method is likely to be a major source of error in any hydrodynamic model.

This paper presents the results of a statistical analysis of the accuracy of three basic techniques, offered by Thompson & Johnson (1985), for interpolating between scattered depth points. The methods tested include bilinear interpolation, inverse-power interpolation and Taylor series interpolation. Initially, the ability of each method to reproduce analytically-generated surfaces was investigated and it was found that all methods performed well with dense bathymetric data. However, some of the interpolation techniques were found to have critical flaws when processing sparsely scattered depth points containing rapid changes in gradient.

Results are presented for a number of analytical test surfaces together with the relatively complex bathymetry of the Gulf of Thermaikos in northern Greece. The tests indicate that Taylor series interpolation is the most accurate technique when the bathymetry varies smoothly in space. However, if the surveyed depth points contain rapid changes in gradient, the Taylor series algorithm is prone to overshoot the supplied bathymetry data, producing spurious peaks and troughs in the interpolated depth field. Under these circumstances, the inverse-power technique becomes the most accurate interpolation procedure. A review of the overall accuracy of each of the methods reveals that bilinear interpolation appears to be the most suitable and robust approach for a wide range of coastal bathymetries.

INTERRELATION BETWEEN STOKES AND PAPKOVICH – NEUBER EIGENMODES FOR SPHEROIDAL STOKES FLOW

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ABSTRACT

The steady and creeping flow of an incompressible viscous fluid is described by the well-known Stokes' equations, connecting the biharmonic vector velocity with the harmonic scalar pressure field. For many interior and exterior flow problems involving small particles, spheroidal geometry provides very good approximation. Therefore, in many important applications the flow is considered to be axisymmetric since the relative physical problems enjoy rotational symmetry. Such motions are characterized from the existence of a stream function, which is employed in order to obtain the velocity and the pressure field. The complete solution of the equation for Stokes flow in spheroidal coordinates can be obtained through the theory of generalized eigenfunctions and this stream function enjoys the representation of a full series expansion in terms of semiseperable eigenmodes. On the other hand, Papkovich (1932) and Neuber (1934) proposed a differential representation of the flow fields in terms of harmonic functions. In the interest of producing ready – to – use basic functions for Stokes flow in spheroidal coordinates, we calculate the Papkovich – Neuber eigensolutions, generated by the appropriate spheroidal eigenfunctions where the full series expansion is being demonstrated. Furthermore, connection formulae are obtained through which any solution of the Stokes system, given in terms of semiseperable eigenfunctions, can be transformed to the Papkovich – Neuber eigensolutions. We show that this procedure is not invertible since these formulae interrelate each Papkovich – Neuber potential with a specific combination of semiseperable eigenfunctions.

NUMERICAL STUDY OF OSCILLATORY FLOW PAST PAIRS OF CYLINDERS AT LOW REYNOLDS AND KEULEGAN-CARPENTER NUMBERS

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ABSTRACT

The oscillatory flow around a circular cylinder is a flow phenomenon which proved a challenging area for research, since it provides an ideal tool for the investigation of flow around a cylinder immersed in a wave environment. The phenomenon is controlled by two dimensionless numbers; the Reynolds number based on the maximum flow velocity and on the Keulegan-Carpenter number, their ratio known as β parameter. The flow pattern is more complicated when pairs of cylinders are considered due to the hydrodynamic interference effects, which depends on the ratio of the distance between the cylinders by the cylinder diameter, defined as gap ratio.

The mathematical model of the problem consists of the well-known Navier-Stokes equations. In the present investigation the finite element technique was favored for the solution of the Navier-Stokes equations, in the form where the stream function and the vorticity are the field variables. The characteristic-Galerkin technique was employed for the temporal discretization, in an attempt to improve the accuracy of the results. At each time level the nodal values of the stream function are calculated from the vorticity values at the previous time level. Then the vorticity on the cylinder surface is derived from a suitable formula and afterwards the nodal values of vorticity throughout the flow field is calculated. The pressure distribution throughout the flow field can be obtained from the solution of Poisson's equation. Unstructured meshes were employed for the solution, for the various configurations.

The streamlines, equi-vorticity lines and isobars at different instants throughout a cycle can be plotted from the nodal values of stream function, vorticity and pressure. From the stream function values, the nodal values of flow velocity have been derived. Finally, the unsteady in-line and transverse forces on the cylinder were also calculated from the pressure and shear around the cylinder surface. The hydrodynamic coefficients of the in-line force were also evaluated. The various flow regimes for the Keulegan-Carpenter and Reynolds numbers examined were identified, providing evidence of the interference effects for each gap ratio examined.

INVERSE DESIGN OF AERODYNAMIC SHAPES USING ANT COLONY OPTIMIZATION

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ABSTRACT

The Ant Colony System (*ACS*) is a recently proposed metaheuristic. In the literature, *ACS*'s have been used to solve stochastic combinational optimization problems, such as the Traveling Salesman Problem (*TSP*) and routing problems. All these problems deal with integer numbers that should be put in the proper order. Conceptually, in the Ant Colonies Optimization (*ACO*) method, ants stand for agents with search capabilities similar to those of real ants. They act synergetically, in populations, usually with constant number of agents. A new population of ants comes after the previous one and inherits coded information about the most promising routes to the optimum solution. This piece of information is in the form of pheromone trails laid down by ants-members of the previous populations.

This paper aims to extend the *ACO* capabilities to new scientific areas, such as the inverse or optimum design of aerodynamic shapes. In the past, other optimization methods, like for instance Genetic Algorithms (*GAs*), have been widely used for the design of ducts of airfoils. The target is the pressure or velocity distribution along the solid walls, at given flow conditions. Inherent to this problem is the parameterization of the shape which specifies the design variables. If Bezier polynomials are used, then the design variables are the coordinates of the control points. Computational Fluid Dynamics (*CFD*) codes—routines are employed for the evaluation of candidate solutions. In contrast to the *TSP* or other combinatorial optimization problems, the inverse design of a shape (*IDS*) is a problem with continuous search space and a complex solution landscape.

The use of *ACO* in this kind of problems is, in fact, novel. To the authors knowledge, this could be the first use of *ACO* in a problem with real(continuous) free parameters. The concept is simple; provided that we do possess an effective *ACO* method (and the relevant software) for solving the *TSP* problem, we employ a mathematical transformation between the *IDS* problem and the *TSP*. The route length, which is the cost function in the *TSP*, is taken to be the deviation of the pressure or velocity distribution along the shape contour from the target one.

For the readers which are not familiar with the *ACO* method, this will be presented in the full paper along with a thorough validation. Then, its novel implementation to the *IDS* problem will be described, followed by some indicative results. Solutions to the *TSP* will first be demonstrated and then the reconstruction of existing airfoils will be presented.

STRATIFIED TWO-PHASE FLOW OF VAPOUR BOUNDARY LAYER-CONDENSATE FILM OVER A CYLINDER

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ABSTRACT

The steady two-dimensional laminar flow of a stream of saturated vapour flowing over a solid surface that is kept at a uniform temperature, below the saturation temperature, is examined. Due to the temperature difference between the vapour stream and the solid surface a film of condensate is generated that flows along the surface due to shear, pressure-drop and gravity. In the limit as the boundary layer and film thickness remain smaller than the radius of curvature of the surface a simplified lubrication-type formulation describes the temperature and flow fields in the film, whereas the usual boundary layer formulation is applied in the vapour boundary layer. The parameters that control momentum and heat transfer in this problem are the viscosity ratio, μ, the density ratio, ρ, the Prandtl number, Pr, the Froude number, Fr, and finally the thickness ratio between the condensate and the vapour boundary layer, ε. Thus, given the operating fluid and the temperature of the saturated vapour, the viscosity ratio, the density ratio and the Prandl number are determined. The other two parameters are determined by defining the free-stream velocity (Fr) and the temperature of the solid surface (ε).

The case of flow past a cylinder is investigated numerically, with the oncoming stream aligned with gravity, following the procedure developed by Smyrnaios et al. and it is shown that, under certain circumstances, the solution in the rear part of the cylinder exhibits two different types of singularity. The first one is associated with vanishing skin friction (wall shear) and rapidly increasing film thickness while the other takes place in the upper fluid (vapour) in a region where very small velocities prevail giving rise to an off-wall separation. In both cases the appearance of a singularity indicates recirculation in the condensate or the vapour stream and, possibly, separation.

It is shown that, given the saturation temperature and the operating fluid, there exists a critical line, $Fr=Fr(\varepsilon)$ in the (Fr, ε) plane, beyond which the type of singularity is altered from 'wall separation' to 'off-wall separation'; see figure below. Preliminary comparison with experimental measurements of the heat transfer coefficient indicate that heat transfer deteriorates when 'wall separation' takes place, owing to an abrupt increase of the film thickness, whereas 'off-wall' separation enhances heat transfer, possibly as a result of recirculation.

Keywords – Boundary Layer - Film Condensation – Forced Convection - Singularity - Heat Transfer Coefficient

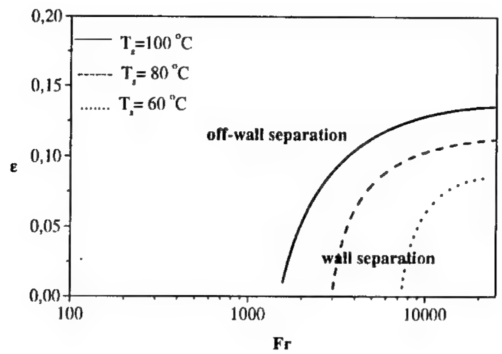

Figure 1: Regions of different type of singularity in the parameter space of (Fr,ε) for the case of steam/water.

References:

[1] Smyrnaios, Pelekasis & Tsamopoulos, to appear in Journal of Fluid Mechanics (2000).

FLUID DISPACEMENT BY AIR IN A CAPILLARY TUBE

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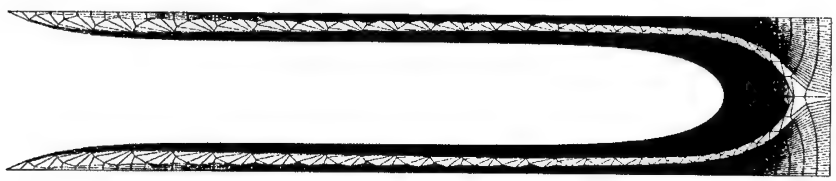
ABSTRACT

When air is forced to displace a more viscous fluid from a tube, a very long bubble is created, with a diameter smaller than that of the tube because fluid adheres to the tube wall. This is known as fingering instability, and is often encountered in practical applications such as oil recovery, production of hollow fiber membranes and gas-assisted injection molding. Although this phenomenon has been studied primarily experimentally for many years, its theoretical study has been restricted to simplified and, usually, steady state models.

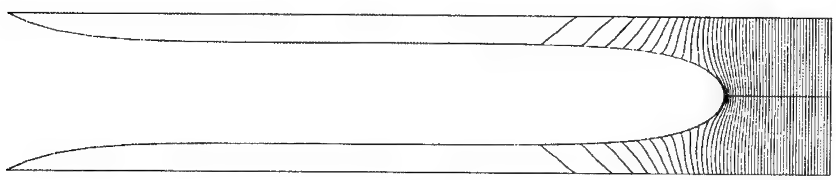
In the present theoretical work we study the transient displacement of a viscous melt by air in a cylindrical tube of constant cross section or with a contraction downstream and under various pressures and isothermal conditions. Neglecting the flow of air, we define as control volume the volume of the melt that is been displaced (see below). The flow field is governed by the mass and momentum balances in their axisymmetric form together with appropriate boundary conditions. The boundary conditions include a local balance between viscous stresses, surface tension and gaseous pressure at the free surface; no slip and no penetration condition at the solid wall and far downstream we assume a fully developed flow. The presence of a highly deformable free surface, a deforming control volume and the stress-singular points demands an accurate, robust and flexible numerical method. The one we have chosen, is the finite element method, together with a system of elliptic partial differential equations, capable of generating boundary-fitted finite element discretizations. Grid points become finite element nodes mapped subparametrically from a patched computational domain. The implicit Euler method is used for time integration.

The dimensionless parameters which arise in the equations are the Suratman number, Su, which measures the importance of inertial and surface tension forces relative to the square of viscous forces, the Bond number, Bo, which measures the importance of body forces against the surface forces, the dimensionless gaseous pressure and various geometrical ratios. We have found that both the finger profile and the thickness of the deposited material on the wall are highly affected by the properties of the displaced fluid. In particular, increasing the Suratman number, the deposited material becomes thinner and the finger profile steeper and when the inertial forces become dominant a secondary, eccentric (annular) finger is formed. In the following figures, we show the discretized physical domain (fig. 1) and the pressure distribution in the viscous fluid (fig. 2) for Su = 0.01, Bo = 0.00, L/R=10.00, $P_{ext}= 1.0x10^4$, and at dimensionless time $\tau = 2.20x10^{-2}$.

Keywords – Fluid Displacement – Fingering Instability – Free Surface Flow – Navier Stokes eqs.



(fig. 1)



(fig. 2)

References:

[1] Dimakopoulos Y and Tsamopoulos J. (2000) "Unsteady displacement of a viscous fluid in a circular tube by air", submitted for publication to *Phys. Fluids*.

FLOW BETWEEN TWO ROTATING HEATED SPHERES

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ABSTRACT

The steady motion in a spherical shell is studied in the presence of heat when the boundaries are rotating. The secondary motion as well as the Nusselt number along a meridional line on the outer boundary are affected by the relative rotation of the two spheres.

AN EXPERIMENTAL METHODOLOGY FOR ENHANCING 2-D FLOW CHARACTERISTICS IN A 3-D TURBULENT FLOW

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ABSTRACT

Pure two-dimensional flows are of theoretical interest. In practice and in nature, three-dimensional turbulent flows with enhanced two-dimensional flow characteristics exist, which are referred in the literature as quasi two-dimensional. One major implication of this term is that one fluctuation velocity component is suppressed compared to the other two. This has been observed, for example, at large atmospheric altitudes, above the earth's boundary layer, where significant air velocity variations are present in planes parallel to the earth's surface, but very weak in the perpendicular direction. A second important flow characteristic associated with two-dimensionality is the presence of a scaling region in the velocity power spectrum which follows a power law with exponent different from -5/3, the value for isotropic, three-dimensional turbulence. The classical theoretical value for two-dimensional turbulence is -3. A quasi two-dimensional flow created in the laboratory can be used for validation of relevant numerical models, which usually assume simplified two-dimensional flow regimes.

The present work was aimed at producing in a wind tunnel a quasi two-dimensional flow in accordance with the velocity power spectrum criterion mentioned above. The flow in the wake of a cylinder was investigated for that purpose. This is essentially three-dimensional, with an inherent two-dimensional character associated with the von Karman street of vortices appearing behind the cylinder. It has been observed that two factors influence the spectral behavior of this flow: the Reynolds number based on the cylinder's diameter, R_D and the state of the cylinder's boundary layer that determines its behavior at separation. In the range $1500 < R_D < 3000$ and with turbulent boundary layer separation, the flow in the region $10 < x/D < 40$ displayed the desired spectral behavior. Referring to the detailed model of the flow field in the wake of a cylinder in cross-flow, proposed by Hussain & Hayakawa (J. Fluid Mech., v.180, pp. 193-229, 1987), a justification is presented for the suppression of the three-dimensional characteristics of the flow at the present experimental conditions and the enhancement of the two-dimensional ones. This is supported by an analysis of the experimental data by a phase-averaging methodology which isolates the periodic (coherent) component of the flow in the wake and examines its behavior in detail.

FORCE FROM JET FLOW ON INCLINED DISCS

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ABSTRACT

An interesting technical topic in the field of Fluid Mechanics is the determination of the force which is exercised on a still solid body when this is submerged in a fluid flow. Usually this force cannot be determined through an analytical approach, but it depends entirely on experimental measurements.

In this experimental work a vertical air jet flow is considered, issuing in the calm atmosphere from a horizontal exit of a pipe and striking on an inclined thin and smooth disc. The exit velocity (x direction) is V_o, the pipe diameter is d_o, the properties of the fluid are its density ρ_o and its kinematic viscosity v_o, and the fluid is considered as incompressible. The disc has a diameter D, its center lies on the jet axis at a distance x from the exit, and has an inclination angle φ to the horizontal. The vertical force exercised on the disc is F and this force is zero when φ = 90° (vertical disc). The practical purpose of this research is to contribute to the determination of forces from air or water jets striking on deflectors or various obstacles.

The basic quantities and parameters of the flow are, the exit fluid discharge $Q_o=V_o \cdot (\pi \cdot d_o^2/4)$, the Reynolds number $Re_o=V_o \cdot d_o/v_o$ – which when large (>100) corresponds to a turbulent jet, the exit momentum $M_o=V_o \cdot Q_o$, and the dimensionless ratios F/M_o and D/x. A large number of experiments have been performed to measure F at various distances x, for a variety of d, D, φ, M_o and Re_o. The pipe diameters were d_o=1-2,5 – 6,45cm, the disc diameters were D=5-10-10,2-14,5-15-20-22,7-25-36cm, the angles φ were φ=0° (horizontal disc)-30° –45° –60°. The Reynolds numbers varied between 25.000 and 135.000 and a number of around 750 forces where measured with the aid of a balance. From dimensional reasoning it can be prooved that

$$F/M_o = \varphi(D/x \text{ and } \varphi).$$

For each angle φ an empirical exponential equation was determined through the corresponding cloud of the experimental points in the form of

$$F/M_o = A \cdot \exp[-19{,}2 \cdot B^2 \cdot (D/x)^2],$$

where A and B had different values for different angles φ. Moreover A and B were compared to the angles φ, in the form of the equations

$A=f(\varphi)$ and $B=F(\varphi)$,

and the pertinent expressions were deduced.

Thus, the final equation

$$F/M_o = f(\varphi) - \exp[-19{,}2.F^2(\varphi).(D/x)^2]$$

was conluded, holding for any angle φ ($\varphi \leq 60^o$), any D/x, and exit velocity. The measurements have been undertaken in the Hydraulics Laboratory of N.T.U.Athens.

FLOW IN OPEN CHANNELS LINED WITH DIFFERENT MATERIALS

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ABSTRACT

This paper presents an experimental research on uniform flows in open channels, lined with different materials. In practice it is usual for a hydraulic Engineer to deal with such cases, e.g. a smoth concrete or asphalt bottom and two lateral symmetric walls from stone, brick, plaques, or other materials.

The most common method to analyze such problems is to determine a constant "average" or "equivalent" Manning's resistance coefficient, n_E, and to use it as a basis for all the hydraulic calculations of the uniform flow, for example,

$$Q = A_*V = A_*(1/n_E)_*R^{2/3}{}_*J^{1/2}, \qquad (1)$$

where Q is the discharge (m^3/sec), A = area of the water cross section (m^2), R= hydraulic radius = A/P (m), P = wetted perimeter (m), J = channel slope-which usually is very small, and V = average cross section velocity (m/sec).

Although, this practice does not reveal some interesting details of the flow structure, and especially the dependence of Manning's coefficient n (for a water depth y) on the parameters of each flow.

In this research a rectangular cross section (b) was considered, and a variety of maximum water depths y_f, with corresponding Manning's n_f were used. The experimental channel had a length of about 11m, a width of b = 25 cm, a slope of J = 0,12%, a metallic bottom and two glass vertical walls.

In order to differentiate the wall roughness from the bottom roughness, a large number of vertical plastic strips were glued on the entire lengths of the sidewalls. Those strips had a rectangular cross section k x h, where k and h were considered along the flow and perpendicular to the walls respectively, and were put to a distance λ.

The dimensions k and h were constant, k = h = 4 mm, while the distances λ were varying, λ = ∞-40-20-10-5 cm. The latter distances were constant for each experiment, but were systematically varying from experiment to experiment. In each experiment the Q and y values were measured, while the $A = y_*b$, P = b+2y, R , and $n = (A/Q)_*R^{2/3}{}_*J^{1/2}$,values were calculated. A similar procedure was followed to measure n_f. A large number of uniform flows were organized with various ratio y/y_f, n/n_f and λ/h.
From dimensional reasoning it can be found that

$$n/n_f = \text{function of } (y/y_f, y_f/b, \lambda/h), \tag{2}$$

while from the experimental data the equation

$$n/n_f = A*(y/y_f)^B*[1-(y/y_f)]^C + y/y_f \tag{3}$$

was deduced, where A and B were determined as functions of y_f/b, and C as a function of λ/k. All the measurement were performed in the Hydraulics Laboratory of the Civil Engineering Dept. - National Technical University of Athens

AIRLIFT PUMP PERFORMANCE OPTIMISATION FOR DEEP-SEA MINING

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ABSTRACT

The Air-Lift Principle is a well-established method for vertical transport of liquids and solid-liquids mixtures. It is based on the principle of injecting a compressed gas, usually air, into the conveying pipe causing thus, under special conditions, the gradual lifting of the liquid or the mixture. The object of the present study is to access and optimise the performance of an airlift pump under predetermined operating conditions, and especially to estimate the effect of the pipe diameter and the injection depth to the airlift pump efficiency.

In the numerical modelling, the gas-liquid-solid three-phase flow in an airlift pump is described by a system of differential equations, which derives from the fundamental conservation equations of continuity and momentum. This approach leads to a more general mathematical model, which is applicable to a wide range of installations, from small airlift pumps to very large systems, suitable for deep-sea mining. The following assumptions are made for the mathematical formulation of the airlift mechanism. The transport of the solid particles occurs primarily through water and an isothermal change of state is assumed for air. The planes of equal velocity and equal pressure should be normal to the pipe axis. This makes the problem one-dimensional which is approximately the case in practice.

In addition, parameters such as the drag coefficient of solid and gas phase, the shape and size of particles and bubbles, and the compressibility factor, which is very important for deep-sea mining, have been incorporated in the governing equations. According to the physical modelling, the liquid is the main phase and there are no interaction forces between bubbles and solid particles. So the velocity of both gas and solid phases is expressed in relation to the velocity of the liquid phase and the relative velocity of the corresponding phase. These are the settling velocity of the solid particles and the rising velocity of bubbles where, in addition, we have to consider the change of the bubble diameter due to the expansion of the gas phase.

The application of the computational algorithm to different geometry and flow conditions of an airlift pump leads to the optimisation of the system. The numerical simulation results clearly show a very good agreement with experimental and computational data of other researchers. The analysis methods have been combined in an easily used computer code, which is a very useful tool for the optimum design of airlift pump systems.

BOUNDARY SHEAR IN COMPOUND NON-SYMMETRICAL CHANNELS

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ABSTRACT

The distribution of boundary shear stresses in complex cross sections is poorly understood. As a result, our knowledge concerning the momentum transfer within the cross section is limited, despite of the practical interest involved. In the cases of compound channels the lateral and vertical momentum transfer between regions of different depth considerably modifies the primary flow field. Consequently it is important to accurately specify this interaction between the flow fields.

The present work deals with the presentation and analysis of experimental results, concerning the boundary shear stresses and boundary shear force distribution in a uniform flow within a smooth open channel with compound cross section, comprising of one rectangular main channel and one non-symmetrical, also rectangular, flood plain. Velocities were recorded using an electronic streamflow miniature propeller meter, while shear stresses were measured with a Preston tube. Typical cross section and dimensions of the channel are presented in Figure 1.

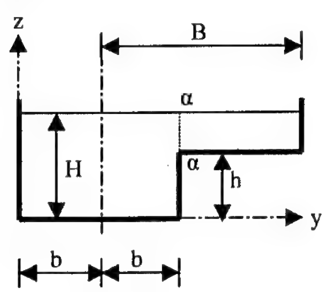

Figure 1 : Typical cross section of a non-symmetrical channel with one flood plain

B+b	381 mm
J_o	$9{,}66 \cdot 10^{-4}$
h	76 mm
2b	152 mm
B-b	229 mm
H	84÷188 mm

Equations are presented giving the boundary shear stress on the flood plain as a percentage of the total shear force. The experimental shear force results are used to derive equations for the lateral and vertical transfer of momentum within the cross section. These results apply only to the smooth channel case and may also be used when describing such flows with mathematical models.

USE OF HEIGHT DENSITY FUNCTION FOR THE EVALUATION OF MEASUREMENTS WITH A LASER DOPPLER ANEMOMETER

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ABSTRACT

Laser Doppler Anemometry (LDA) is a non-intrusive, optical technique for local, time evolving measurements of velocities in fluids. Two parallel Laser beams are focused on a control volume. Light scattered on seeding particles is collected on a photo-detector. Interference due to scattering from two beams with different propagating unit vectors results to a signal with frequency proportional to the local velocity of the flow. Phase Doppler Anemometry (PDA) is an extension of LDA technique measuring the size and velocity of small spherical particles, in dispersed two phase flows. The velocity measurement is accomplished as in LDA, but collecting the scattered field in different directions using at least two photodetectors PDA is capable to provide size information based on the phase difference of the signals.

LDA and PDA signal processing systems are capable to evaluate the properties of a particle crossing the measuring volume depending on the particle trajectory and velocity magnitude. For this reason the sensitivity of these systems is different for different directions, introducing a bias to the measurements. Since in most processing systems a particle is evaluated only once during its passage through the measuring volume the important parameter is the effective cross sectional area in each direction **n**.

In the present work the height density function is introduced as a means to analyze the measuring volume properties for Laser Doppler Anemometry (LDA) and Phase Doppler Anemometry (PDA) systems in order to provide unbiased estimators for the reduction of flow data as well as error estimation. The height distribution function $G_n(L)$ is defined so that if A_n

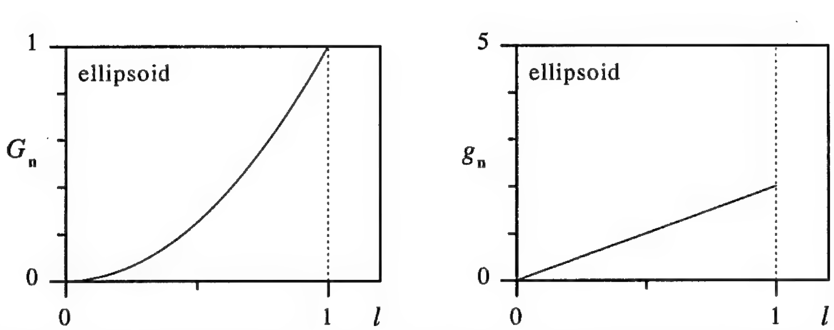

Figure 1. Normalized height distribution, G_n, and height density, g_n, functions for an ellipsoid

is the projection of a volume to a plane normal to **n**, the product $A_n G_n(L)$ gives the total area of the projection corresponding to parts of the volume with height less than L in direction **n**. Correspondingly a height density function $g_n(L)=dG_n(L)/dL$ is defined. Functions $G_n(L)$ and $g_n(L)$ are analytically determined for an ellipsoid (figure 1). These results are used for the estimation of the effective cross sectional area of LDA measuring volumes as a function of the velocity magnitude and direction

DAMAGE MODELS FOR VISCOELASTIC COMPOSITES

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ABSTRACT

Homogenized constitutive equations and some related experimental results for viscoelastic composite materials with constant or growing damage are described and compared. Behavior of both fiber and particle-reinforced composites is discussed.

First, a composite consisting of a linearly viscoelastic matrix with a rigid reinforcement phase and distributed, propagating microcracks is analyzed. Homogenized constitutive equations are developed and combined with expressions for damage evolution based on viscoelastic crack-growth theory. We then use this three-dimensional theory, together with experimental results, to characterize a highly-filled rubber; this composite is initially isotropic, but becomes strongly anisotropic due to microcracking. Predictions of loads and displacement fields in specimen geometries (with and without holes and macroscopic cracks) not used in the characterization process are made and compared to experimental results. Agreement is very good.

Application of the constitutive theory to a fiber composite with growing damage is then discussed. We describe an experimental program in which acoustic emissions are used to obtain evidence on damage growth and how it is affected by different loading histories. It is shown that the damage, as determined from acoustic emissions for different loading histories, can be correlated using a damage measure that was developed from the theory.

Finally, we briefly describe a generalized constitutive theory that accounts for microcrack growth and nonlinear viscoelastic behavior of the matrix phase.

DAMAGE LOCALISATION AND FRACTURE IN LAMINATE COMPOSITES

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ABSTRACT

A major challenge in composite design is to calculate the intensities of the damage mechanisms for a composite structure subjected to complex loading at any point and at any time until the final fracture which arrives after strain and damage localisation. Damage refers to the more or less gradual developments of microcracks (transverse or not) which lead to macrocracks and then to rupture; macrocracks are simulated as completely damaged zones. A solution for laminate composites is based on what we call a damage mesomodel. It is a semi-discrete model for which the damage state is uniform throughout the thickness of each single layer; as a complement, continuum damage models with delay effects combined with a dynamics analysis are introduced.

At the meso-scale, characterized by the thickness of the plies, the laminate structure is described as a stacking sequence of homogeneous layers through the thickness and of interlaminar interfaces. Two basic constituents are then introduced: the single layer and the interface. The corresponding models have to be valid for any stacking sequence and any loading. The main damage mechanisms are described as: fiber breaking, matrix microcracking, fiber debonding and delamination of adjacent layers. This laminate meso-model has been used for various continuous fiber laminates, essentially for aeronautical and spatial applications.

Another approach is to use micromechanics models which are strongly connected to micro-observations of the different microcracking mechanisms. However, this approach is at present time, far to be completely achieved for final fracture and localisation prediction.

This paper is an attempt to bridge micromechanics and mesomechanics of laminates composites in order to get a better understanding and prediction of localisation and final fracture. The central point to be discussed is the main homogenization hypothesis which is used to describe any stacking sequence for any loading through only two elementary constituents: the single layer and the interface.

CYLINDRICAL SHELLS AND THEIR STABILITY (CHOICE OF THE DEFLECTION FUNCTION AND CRITICAL EXTERNAL RADIAL PRESSURE)

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ABSTRACT

The intention of the present contribution is to give an overview of the research concerning the theoretical approach to one of interesting and important engineering problems, to the loss of stability of a cylindrical shell subjected to the external radial pressure.

In the previous research a certain general formula for the critical external radial pressure was derived. It was shown that the procedure can be applied to the shells with different boundary conditions. Not only to the shells with symmetrical, both fixed or simply supported ends, but also to the shells with nonsymmetrical supported ends, one fixed and the other simply supported. It seems that the last mentioned case was not previously treated.

The generality of the derived expression consisted in the fact that it could be reduced to the different known formulae for the described boundary conditions and they appeared to be just its particular cases.

The next step of the research was the proposition of a new formula for practical applications.

As the consequence of the above mentioned research there appeared the idea to try to investigate different forms and types of deflection functions that can be used for the solution of the considered problem and their influence on the form of the expression for the critical pressure. The deflection function was assumed as the potential function, after that in the sinusoidal form and finally as an exponential function. For all cases the coresponding expressions for the critical pressure were derived.

The deflection function was also assumed at first in such a way that it could describe some idealized form of the deformed shell (deflections constant in the longitudinal direction) and after that in the form describing much better the real situation (deflections not constant along the shell).

ESSENTIAL STRUCTURE OF DAMAGE MECHANICS MODELS

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ABSTRACT

This presentation is based on the assumption that the models of damage mechanics should be based on the thermodynamics of irreversible processes and fracture mechanics. Hence, the continuum models of the damage mechanics must be deduced using the principle thermodynamics with internal variables. These principles are applicable only when the irreversible process of damage evolution can be approximated to a sequence of thermodynamic states equilibrated by thermodynamic forces that are conjugate to the internal variables.

A proper selection of internal variables, their conjugate forces and macro parameters of the equilibrium states must be based on the principle of the fracture mechanics. Using the thermodynamics of stable propagation of cracks it is shown that the force that drives damage evolution is related to the elastic energy release rate and the resisting force is related to the cohesive energy. However, both forces are also related to the statistical properties of the material on the micro-scale.

The most important role of damage mechanics is to estimate the onset and mode of failure that requires modeling the process of damage evolution that is "far" from the equilibrium. This is necessary when the microcracks form clusters in the form of microcrack in tension and faults in when the specimen is in compression. Applying novel models of statistical physics it was possible to demonstrate that the "distance" from the equilibrium can be identified and measure in laboratory and in situ. The same measure can be related to the earthquakes and other processes of self-organizations.

The presentation is supported by several examples, such as the strain localization and penetration, which are also of engineering interest.

FATIGUE OF MATERIALS AND STRUCTURES

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ABSTRACT

Fatigue: an old phenomenon but still an actual problem as it represents most of the in service structure failures. It will be shown how damage mechanics can be used as a predictive tool in order to decrease the risk of low cycle fatigue or high cycle fatigue fractures.

LARGE DEFLECTION ANALYSIS OF BEAMS WITH VARIABLE STIFFNESS. AN ANALOG-EQUATION SOLUTION

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ABSTRACT

In this paper the Analog Equation method (AEM), is employed to analyze an initially straight Bernoulli-Euler beam undergoing large displacements with small strain and rotation (intermediate nonlinear theory). In this case the transverse deflections influence the axial force and the resulting governing differential equations are coupled and nonlinear. The formulation is in terms of the displacements components. Using a variational procedure the following equilibrium equations are derived

$$\frac{d}{dx}[EA(u_{,x}+\frac{1}{2}w_{,x}^2)]=-p_x \tag{1a}$$

$$\frac{d^2}{dx^2}(EIw_{,xx})-\frac{d}{dx}[EA(u_{,x}+\frac{1}{2}w_{,x}^2)w_{,x}]=p_z \tag{1b}$$

together with the boundary conditions at $x=0$ and $x=L$

$$\alpha_1 u+\alpha_2 N=\alpha_3 \tag{2a}$$

$$\beta_1 w+\beta_2 V=\beta_3 \tag{2b}$$

$$\gamma_1 w_{,x}+\gamma_2 M=\gamma_3 \tag{2c}$$

In the above equations $u=u(x)$ is the axial and $w=u(x)$ the transverse displacement; $p_x=p_x(x)$, $p_z=p_z(x)$ are the axial and transverse distributed loading, respectively; E is the Young's modulus; $A=A(x)$ is the varying cross-sectional area of the beam and $I=(x)$ is the moment of inertia of the cross-section. Moreover, $\alpha_{i,}\ \beta_i,\gamma_i$ are given constant. These boundary conditions are the most general linear ones associated with the problem and can include elastic support or restrain. N is the axial force, M the bending moment and V the transverse support reaction.

The boundary value problem described by eqns (1) and (2) is solved using the concept of the analog equation. According to this method the two coupled nonlinear differential equations are replaced by two uncoupled linear ones pertaining to the linear axial and transverse deformation of a beam with unit axial and bending stiffness, respectively, under fictitious loading. Namely,

$$\frac{d^2u}{dx^2}=q_1(x) \tag{3a}$$

$$\frac{d^4u}{dx^4}=q_2(x) \tag{3b}$$

where $q_1(x)$, $q_1(x)$ are fictitious loads. Subsequently, these loads are established by developing a procedure based on the boundary integral equation method. Thus, the solution of

the original problem (1a,b) is given by the integral representations of the substitutes equations (3a,b), i.e.

$$u = c_1 x + c_2 + \int_a^b G_1(x,\xi) q_1(\xi) d\xi \tag{4a}$$

$$w = c_3 x^3 + c_4 x^2 + c_5 x + c_6 + \int_a^b G_2(x,\xi) q_2(\xi) d\xi \tag{4b}$$

where c_i $(i = 1,2,\ldots 6)$ coefficients determined from the boundary conditions and $G_i(x,\xi)$ $(i = 1,2)$ are the fundamental solutions of eqns (3a,b), that is a particular singular solution of each of the following equations

$$\frac{d^2 G_1}{dx^2} = \delta(x-\xi) \tag{5a}$$

$$\frac{d^4 G_2}{dx^4} = \delta(x-\xi) \tag{5b}$$

with $\delta(x-\xi)$ being the Dirac function.

The derivatives of the displacements required for the evaluation of the stress resultants are obtained by direct differentiation of eqns (4a,b).

Several beams are analyzed, which illustrate the applicability, efficiency and accuracy of the method. A significant advantage of this method is that the displacements as well as the stress resultants are computed at any point and whenever needed using the respective integral representation as mathematical formulae.

References:

[1] Katsikadelis JT. The analog equation method - A powerful BEM-based solution technique for solving linear and nonlinear engineering problems. Boundary Elements XVI. Southampton: CLM Publications, 1994: 167-182.

[2] Katsikadelis JT, Nerantzaki MS. The boundary element method for nonlinear problems. Engineering Analysis with Boundary Elements 1999; 23: 365-373.

CRUSHING OF SHIP'S BOW STRUCTURE DURING COLLISION WITH BRIDGE PIERS

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ABSTRACT

During ship collision with bridge piers impact forces are highly influenced by crushing properties of a ship's structure. However, most researches concerning ship impact problems are devoted to the sea going ship collisions with bridge piers and other marine structures. The significant differences in sizes, shapes and structure properties made these results almost inapplicable for the collision problems of vessels that are used in inland waterways.

In this paper a method that the authors used for the analysis of a river ship - bridge pier impact problem is presented. The main part in this method is a model for predicting the crushing force - deformation (indentation) response of a ship. The behavior of a ship's bow structure during the collision is idealized with the folding mechanism model. This model is developed in order to trace the principal features of a ship's structure crushing process during the collision. At early stages of a contact, the response is mainly governed by buckling and bending of the ship's deck and bottom structure. Later, the axial stressing of ties formed during the folding of the ship's deck and bottom structures are dominant. The problem is treated as a quasi static, as strain rate effects are neglected. The folding mechanism model is described in detail and crushing force-deformation functions in the cases of head-on-bow and skew impacts of a characteristic river ship are given. The theoretical predictions are compared with the results of experimental investigation performed in Germany. At the final part of the paper, the presented model is used for the evaluation of impact forces during the collision of a characteristic ship with a bridge pier.

BEM SOLUTION OF VISCOPLASTIC PROBLEMS IN METALLIC STRUCTURES IN THE PRESENSE OF TEMPERATURE GRADIENTS

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ABSTRACT

The problem of inelastic analysis of metallic structures under elevated temperature conditions is of considerable importance. The numerous engineering applications of metals at elevated temperatures have prompted in recent years a great amount of research interest in the area of their high temperature inelastic behavior close especially to stress concentration areas. Mathematical modelling of time-dependent inelastic deformation in metallic structures has traditionally been carried out by superposing elastic, time-dependent plastic and time-dependent creep strains to obtain the total strain in a structure. Generally, strain-hardening and time-hardening theories are used to model viscoplastis deformation. But it has been proved that these theories are incapable to of describing all the silent features of high temperature deformation behavior of metals. Recently, several researchers have proposed some new theories, known as state variable theories, to overcome these drawbacks of classical theories and to obtain a more faithful representation of high temperature deformation behavior of metals. According to these theories time-independent plastic strain and time-dependent creep strain can be combined into a single quantity called inelastic strain which is time and history dependent. Thus, separate descriptions for these two strains is no longer necessary. As can be expected, closed analytical solutions are only possible in very few cases. These theories use some state variables in order to completely characterize the present deformation state of the metallic material and the history dependence of the rate of nonelastic strain up to the current time is assumed to be completely taken into account by their current values.

The present paper is concerned with the application of the Boundary Element Method (BEM) to the viscoplastic deformation of metallic cylindrical plates under thermal loading conditions. The constitutive relations due of Hart state variable theory are employed to obtain the numerical results. In the proposed formulation, in addition to the use of boundary elements is made use of interior, as well, elements in order to take care of surface integrals due to inelasticity and thermal loading. The numerical results presented are discussed in the context of Hart's theory and the computational scheme, and very encouraging conclusions are drawn.

ROCK DISCONTINUITIES IN TUNNEL DESIGN: NUMERICAL SIMULATION OF THE EFFECTS OF FILLED AND OPEN JOINTS

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ABSTRACT

The structural stability of tunnels and underground openings excavated in rock are often analyzed using numerical procedures including that of finite element analysis. Such analyses are performed either in 2D sections or in 3D space depending on the assumptions, techniques and required accuracy. The presence of discontinuities in the host material, adds to the complexity of such problems since additional assumptions regarding their geometry and properties have to be stipulated.

In this paper, a set of parallel rock discontinuities intersecting a circular opening in elastic and homogenous material at 45 degrees is modeled in 2D space using the finite element method. Two cases are compared with the following characteristics: In the first case discontinuities, which are modeled as very thin material layers, are assumed to be filled with clay, i.e. a material with elastoplastic behavior. In the second case the discontinuities are modeled as open joints (no infill material), by using contact elements, i.e. elements that allow for shearing when in compression but which exhibit negligible tensile strength when in tension.

Differences in the resulting displacement and stress fields around the opening are compared and critically evaluated and comparative diagrams are presented.

References:

1. Lei XY, Swoboda G, and Zeng G., "Application of contact-friction interface element to tunnel excavation in faulted rock" Computers and Geotechnics 17 (1995).
2. Hook E, Kaiser P.K and Bawden WF, "Support of Underground Excavation in Hard Rock", Balkema 1995.
3. Goodman R.E., Introduction to Rock Mechanics, Wiley 1989.
4. Kumar P., "Slip Zones Around Circular Openings in a Jointed Hoek-Brown Medium", Int. J. Rock Mech. Min. Sci. Vol 34, No 6, 1997.

ON THE NUMERICAL PERFORMANCE OF A SIMPLIFIED METHOD OF ANALYSIS FOR CREEPING STRUCTURES LOADED CYCLICALLY

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ABSTRACT

The time stepping calculations to find the response of a structure subjected to a set of applied loads are quite time consuming and often numerically unstable. When the loading is cyclic, simplified methods of analysis may be used instead. These methods are based on the fact that, for stable materials in the sense of Drucker's stability postulate, the stresses and strains become eventually cyclic and therefore, they attempt to evaluate this cyclic stress state right from the start of the calculations.

In the paper, the numerical performance of a new simplified method that was proposed by Spiliopoulos [1] and may be applied to creeping structures subjected to cyclic loading of any period is investigated. The sought long-term cyclic stress in the structure is split into two parts: a cyclic elastic one in response to the loading and a cyclic residual stress part due to the inelastic creep. By discretizing the structure into finite elements the elastic part can be found in the normal way. For the unknown residual stress system, the key point of the simplified method is to decompose it in Fourier series. Thus the problem is converted in one to find the Fourier coefficients of the various terms of the series. An iterative process to calculate these terms is being set up which is based on evaluating, at discrete time points inside the cycle, the time derivatives of the residual stresses at the structure's Gauss points; this can be done by satisfying equilibrium and compatibility at these time points. An update of the Fourier coefficients, based on integrating numerically over the cycle period, then takes place. In order to get convergence, a special acceleration numerical procedure is used and various aspects of the procedure are discussed in the paper. Numerical examples of one-dimensional and axisymmetric problems are presented.

References:

[1] K.V. Spiliopoulos. Simplified methods for the steady state inelastic analysis of cyclically loaded structures. In D. Weichert and G. Maier, editors, *Inelastic Analysis of Structures Under Variable Loads: Theory & Engineering Applications*, Dodrecht, Kluwer Academic Publishers, (2000).

STATIC AND DYNAMIC ANALYSIS OF SHELL PANELS USING THE ANALOG EQUATION METHOD

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ABSTRACT

There are several investigations involved in the application of BEM to solve shell problems. In general, the shell problems are formulated in terms of the displacement components. This formulation leads to three coupled differential equations with variable coefficients. For this reason attempts to apply BEM to shell problems come across to the establishment of the fundamental solution, which is either impossible to determine or impractical to use due to complicated computations. Therefore, with the exception of some D/BEM formulations, the application of BEM to shell problems is rather limited, when compared with potential, elasticity or plate problems. In general, effort has been given to alleviate BEM from the difficult problem of establishing the fundamental solution when applied to shell problems and to use simple known fundamental solutions, as those of the harmonic and biharmonic equations. The proposed method is based on the concept of the *Analog Equation*. Therefore it is referred as Analog Equation Method (AEM). According to the AEM the three coupled differential equations are replaced by two membrane equations for the membrane displacements and a thin plate equation for the transverse displacement in which the body force terms play the role of three fictitious time-dependent load distributions. Subsequently, using a procedure based on BEM the fictitious loads are established and the solutions are obtained from the integral representation of the solutions of the analog equations. This method has been employed to a variety of engineering problems including potential problems [1], elasticity problems [2], plate problems [3], elastic membrane problems, linear and nonlinear static [4] as well as dynamic [5] ones. Although the method can be used to solve shells of arbitrary geometry subjected to any admissible boundary conditions, in this paper it is applied for the cylindrical shells, and particularly for the static and dynamic analysis of thin cylindrical shell panels of arbitrary plan form, which may have holes or cut-offs. The Flügge type differential equations are used. Numerical examples are presented for the static as well as the dynamic shell analysis to illustrate the efficiency and the accuracy of the proposed method.

References:

[1] Katsikadelis, J. T. (1994): The Analog Equation Method-A Powerful BEM-based Solution Technique for Solving Linear and Nonlinear Engineering Problems. In: Brebbia C. A. (ed), *Boundary Element Method XVI*, Southampton: CLM Publications, pp. 167-182.

[2] Katsikadelis, J. T.; Kandilas, C. B. (1997): Solving the Plane Elastostatic Problem by the Analog Equation Method. *Computers and Structures,* 64, pp. 305-312.

[3] Katsikadelis, J. T.; Nerantzaki, M. S. (1994): "Non-linear Analysis of Plates by the Analog Equation Method". *Computational Mechanics*, 14, pp. 154-164.

[4] Katsikadelis, J. T.; Nerantzaki, M. S. (1999): "The Boundary Element Method for Nonlinear Problems". *Engineering Analysis with Boundary Elements*, 23, pp. 365-373.

[5] Katsikadelis, J. T.; Nerantzaki, (2000): A Boundary-Only Solution to Dynamic Analysis of Non-homogeneous Elastic Membranes. *Computer Modeling in Engineering Science*, 1, (3), pp. 1-9.

NUMERICAL STUDIES OF ANCHORS AND REBARS IN CONCRETE SPECIMENS BY DAMAGE MODELS

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ABSTRACT

Anchors and rebars in concrete are usually used as load transfer mechanisms. In many applications, full displacement continuity is usually assumed between the two materials (steel and concrete) in order to simplify the solution. However, these materials have completely different mechanical behaviour and slip interface may occur during the loading. This lack of compatibility leads to bond failure and sliding of rebars and anchorages which is followed by the formation of cracks in concrete in a region around the anchor or rebar. The typical concrete failure scheme is a pulled out concrete cone.

In order to characterize the bond behaviour, experimental studies, widely known as pull-out tests, were performed in the background of a research project. The tests were performed using normal and high performance concrete with steel fibers. A wide variety of concrete types were used in the experimental part of this research. Two types of rebars and three different industrial types of anchors were used in pull out tests.

Three finite element models have been developed for the description of the concrete, steel and the bond behaviour during the pull-out test. All three models incorporate simple damage theories according to which the decrease of the strength of each material component is governed by a continuous functions of an introduced damage function the value of which ranges between zero (undamaged stress state) and unity (completely loss of material coherence). The basic parameter of these damage functions is a stress or strain measure, which is usually expressed in terms of principal stresses or strains for each material. The developed finite elements have been introduced to the open library of a global 3-D FEM code, developed by the authors.

In this paper, the theoretical part of the developed models and their application to the prediction of the experimental results are presented. The model predicted behaviour is found in good agreement with the experimental one. Finally, the implications of the model application in practice are discussed.

ON THE FLEXURAL MODES OF THE BICKFORD BEAM THEORY

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ABSTRACT

This study deals with the construction and documentation of the frequency equations and the characteristic functions of a general three-degrees-of-freedom theory that describes the plane motion of shear deformable elastic beams. The governing equations of this shear deformable beam theory involve a general shape function of the transverse beam co-ordinate parameter, the a-posteriori choice of which specifies the distribution of the transverse shear strain or stress along the beam thickness. Different choices of this shape function produce, as particular cases, the corresponding governing equations of different beam theories. These include the differential equations of the classical beam theory due to Euler-Bernoulli [1,2] as well as the corresponding equations of the shear deformable theories due to Timoshenko [3,4] and Bickford [5].

Since corresponding developments of the Timoshenko beam theory are already available in the literature [6], the Bickford theory is considered as the pilot beam theory in this study. Unlike however the corresponding analysis presented in [7], we consider a slightly modified version of Bickford's theory that, by ignoring some higher-order inertia terms, simplifies the mathematical derivations without affecting considerably the most important of the numerical results. The frequency equations, the characteristic functions and the orthogonality conditions of this theory, which assumes a through-thickness parabolic distribution of the transverse shear strain or stress, are constructed analytically for all the classical sets of boundary conditions applied at the beam ends. Contrary to the Euler-Bernoulli or the Timoshenko beam theories, which are quoted by choosing a constant (zero) or a linear shape function, respectively, in the Bickford theory the parabolic choice of the shape function converts a fourth order operator involved into a sixth order differential equation. Numerical results are also presented and discussed.

References:

[1] R.E.D. Bishop and D.C. Johnson 1960, The Mechanics of Vibration, Cambridge University Press.
[2] J.W.S. Rayleigh 1877-1878, The Theory of Sound, London, McMillan.
[3] S.P. Timoshenko 1921, Philosophical Magazine 41, 744-746. On the correction for shear of the differential equation for transverse vibration of prismatic bars.
[4] S.P. Timoshenko 1922, Philosophical Magazine, 43, 125-131. On the transverse vibration of bars of uniform cross section.

[5] W.B. Bickford 1982, Developments in Theoretical and Applied Mechanics 11, 137-150, A consistent higher-order beam theory.

[6] T.C. Huang 1961, Journal of Applied Mechanics, 28, 579-584. The effect of rotary inertia and of shear deformation on the frequency and normal mode equations of uniform beams with simple end conditions.

[7] K.P. Soldatos and C. Sophocleous, 2001, Journal of Sound and Vibration, (to appear). On Shear Deformable Beam Theories: The Frequency and Normal Mode Equations of the Homogeneous Orthotropic Bickford Beam.

A REALISTIC ESTIMATION OF THE EFFECTIVE BREADTH OF RIBBED PLATES

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ABSTRACT

In this paper a realistic estimation of the effective width of plates reinforced with a system of parallel beams is presented. This problem is of great interest in the analysis of bridge decks or long span slabs. The use of structural plate systems stiffened by beams improves their strength and performance as it minimizes their dead weight.

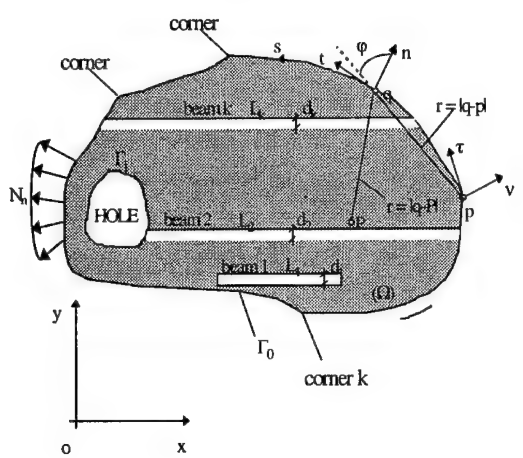

Fig.1. Two dimensional region Ω occupied by the plate.

The arbitrarily shaped ribbed plate system of Fig. 1 is laterally loaded and may be subjected to any type of transverse and inplane boundary conditions. It is analysed using a model which takes into account the resulting inplane forces and deformations of the plate as well as the axial forces and deformations of the beam, due to combined response of the system. The analysis consists in isolating the beams from the plate by sections parallel to the lower outer surface of the plate (Fig.2a,b). The forces at the interface, which produce lateral deflection and inplane deformation to the plate and lateral deflection and axial deformation to the beam, are established using continuity conditions at the interface.

Elimination of the plate membrane stresses leads to a realistic estimation of the effective width of the stiffening beams. The solution of the arising plate and beam problems which are nonlinearly coupled, is achieved using the Analog Equation Method (AEM).

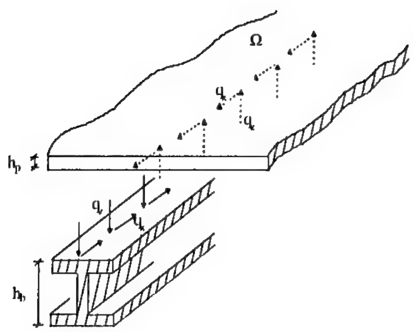

Fig.2a. Thin elastic plate stiffened by a beam.

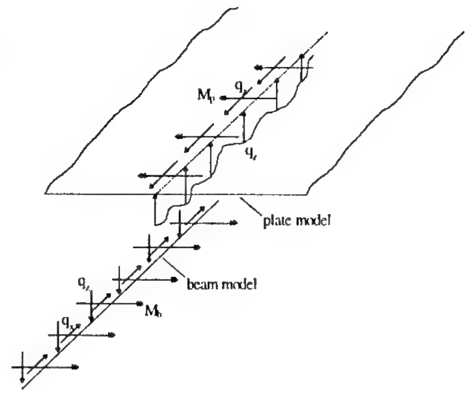

Fig.2b. Structural model of the plate-beam system.

The aforementioned model leads to the following boundary value problems describing the behaviour of the plate and the beams.

The boundary value problem for the deflection $w_p = w_p(\mathbf{x}), \mathbf{x} \in \Omega$ of the plate subjected to the lateral load g as well as to the unknown inplane forces at the interfaces is given from the following equations

$$D\nabla^4 w_p - \left(N_x \frac{\partial^2 w_p}{\partial x^2} + 2N_{xy} \frac{\partial^2 w_p}{\partial x \partial y} + N_y \frac{\partial^2 w_p}{\partial y^2} \right) = g - \sum_{k=1}^{K} \left(q_z^{(k)} + \frac{\partial M_p^{(k)}}{\partial x} \right) \delta(y - y_k) \text{ in } \Omega \quad (1)$$

$$\alpha_1 w_p + \alpha_2 V_n = \alpha_3 \quad (2a)$$

$$\beta_1 \frac{\partial w_p}{\partial n} + \beta_2 M_n = \beta_3 \quad \text{on } \Gamma \quad (2b)$$

where $D = E_p h_p^3 / 12(1-v^2)$ is the plate flexural rigidity with E_p being the elastic modulus and v the Poisson ratio; $N_x = N_x(\mathbf{x})$, $N_y = N_y(\mathbf{x})$, $N_{xy} = N_{xy}(\mathbf{x})$ are the membrane forces per unit length of the plate cross section; $\delta(y - y_k)$ is the Dirac's delta function in the y direction; $q_z^{(k)}$ is the transverse interface force of the *k-th* beam; $M_p^{(k)}$ is the bending moment due to the eccentricity of the q_x component of the interface forces parallel to the *k-th* beam; M_n and V_n are the bending moment normal to the boundary and the effective reaction along it, respectively.

The boundary value problem for the deflection $w_b(x)$ of each beam is given from the following equations

$$E_b I_b \frac{d^4 w_b}{dx^4} - N_b \frac{\partial^2 w_b}{\partial x^2} = q_z - \frac{\partial M_b}{\partial x} \quad \text{in } L_k,\ k = 1,2,\dots,K \quad (3)$$

$$a_1 w_b + a_2 V = a_3 \quad (4a)$$

$$b_1 \frac{\partial w_b}{\partial x} + b_2 M = b_3 \quad \text{at the beam ends } x = 0,\ l \quad (4b)$$

where $E_b I_b$ is the flexural rigidity of the beam; $N_b = N_b(x)$ is the axial force at the neutral axis; V, M are the reaction and the bending moment at the beam ends, respectively and a_i, b_i $(i = 1,2,3)$ are coefficients specified at its boundary.

The unknown functions of the described problem are the deflections of the plate and the beam w_p and w_b, respectively, as well as the components of the forces at the interfaces q_x, q_z. The additional unknowns appearing in this model q_x, q_z are established using the continuity conditions arising from the following physical considerations:

a) The traction components on the interfaces are equal in magnitude and opposite in direction (equilibrium).
b) The transverse displacement components along the beam and in the vertical direction remain continuous across the interfaces, since it is assumed that the plate and the beams are firmly bonded together.

It is noteworthy that the above equations are coupled and non-linear.

The aforementioned problems are solved numerically using the Analog Equation Method (A.E.M.). Elimination of the plate membrane stresses arising from both the inplane interface forces and the inplane boundary conditions leads to a realistic estimation of the effective width of the stiffening beams. Several example problems are treated and the results are compared with those of various regulations. The influence of the plate inplane boundary conditions to the effective width of the stiffening beam is also investigated.

References

1. Sapountzakis E.J. and Katsikadelis J.T. (2000) "Elastic Deformation of Ribbed Plate Systems Under Static, Transverse and Inplane Loading", *Computers and Structures*, Vol.74, pp.571-581.

2. Sapountzakis E.J. and Katsikadelis J.T. (1999) "Dynamic Analysis of Elastic Plates Reinforced with Beams of Doubly-Symmetrical Cross Section", *Computational Mechanics*, Vol.23, pp.430-439.

3. Sapountzakis E.J. and Katsikadelis J.T. (2000) "Analysis of Plates Reinforced with Beams", *Computational Mechanics*, Vol.26, pp.66-74.

ON THE STUDY OF TIE PLATES IN PIN CONNECTIONS

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ABSTRACT

Connections are essential elements of a structure and extensive research is done in recent years on their behaviour. Pin connections are widely used in steel structures. The objective of this work is the study of tie plates in pin connections. Tie plates are also used as components of lifting modules and bridge restrainers.

In certain cases, as e.g. in bracings, pin connections are not supposed to carry any load under normal loading conditions. They must respond to loading only under seismic or other horizontal excitation. The particular behaviour of tie plates in such cases has not been studied very well.

Because of the fundamental concept of the behaviour of pin connections, there is a significant clearance between the tie plate hole and the pin. A research computer programme has been used, in order to take into account in the analysis the arising unilateral contact phenomena. The stress-state of the assemblage has been determined, through a parametric study, by the use of the finite element method. The results of the analysis have been compared with both the specifications of Eurocode 3 and with some experimental data.

THE EFFECT OF DECK ROUGHNESS IN CONJUNCTION WITH OTHER PARAMETERS ON THE DYNAMIC RESPONSE OF STEEL HIGHWAY BRIDGES UNDER VEHICULAR LOADING

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ABSTRACT

The present work examines in detail the effect of the deck roughness on the dynamics of steel highway bridges acted upon by constantly moving loads. Mainly there are three specific problems that must be overcome, in order to determine the aforementioned effect. The first problem is closely related with the efficient and simultaneously numerically adequate simulation of the roughness of the deck, the second is connected with the vehicle model adopted whilst the third with the analytic evaluation of the impact forces between the deck and the wheels. In as much as, this investigation idealizes the deck roughness with a saw tooth function of two parameters, while the vehicle model accounted for consists two identical sub-models of constant distance, each of them consisting of a lumped mass connected with a spring-damper with the wheel mass; the wheel is assumed to be in contact with the deck before impact along a certain flat surface-line, the dimensions of which depend on the diameter of the wheel as well as the vehicle load. Furthermore, the impact forces, which may excite the vehicle model and cause large dynamic loads to be applied on the bridge, are determined analytically on the basis of the most general assumptions of impact theory. The forced vibrations of the bridge, considered as a simply supported elastic beam, are studied thereafter, under the combined action of the moving masses vehicle model and the impact forces. Employing a series solution, the differential equations of forced lateral motions are dealt with analytically and a variety of numerical results are presented in both tabular and graphical form. The effect of the foregoing parameters is comprehensively discussed, focusing on the roughness of the deck and its role on the amplification of the maximum dynamic deformations, forces and moments developed on the beam.

LQR AND H^{∞} OPTIMAL STRUCTURAL CONTROL IN ASEISMIC DESIGN

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ABSTRACT

A number of modern tools in optimal structural control will be reviewed and used in typical structural dynamics' applications. Emphasis is given on robust control principles, which are not very familiar in the civil engineering community.

The use of modern computational tools allows for the application of the above tools with less efforts. Typical examples from aseismic design will be presented and discussed in details. The reported work continues our recent research efforts, which have been documented in [1][2].

References:

[1] E.C. Zacharenakis, K.G. Arvanitis, Sampled-data minimum H-infinity-Norm regulation in structural analysis using multirate-output controllers. ZAMM 80(6), pp. 363-376, 2000.

[2] E.C. Zacharenakis, G.E. Stavroulakis, Optimization for classical and H-infinity structural control: Theory and numerical experiments using MATLAB and SIMULINK. Computational Methods for Shell and Spatial Structures IASS-IACM 2000 (CD Proceedings of the Fourth International Colloquium, Chania, June 4-7, 2000) Eds. M. Papadrakakis, A. Samartin and E. Onate, ISASR-NTUA, Athens, Greece, 2000.

RELIABILITY BASED OPTIMIZATION USING NEURAL NETWORKS

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ABSTRACT

In this paper a robust and efficient methodology is presented for treating large-scale reliability-based, structural optimization problems. The optimization part is performed with evolution strategies, while the reliability analysis is carried out with the Monte Carlo simulation (MCS) method incorporating the importance sampling technique for the reduction of the sample size. The elasto-plastic analysis phase, required by the MCS, is replaced by a neural network predictor in order to predict the necessary data for the MCS procedure. The use of neural networks is motivated by the approximate concepts inherent in reliability analysis and the time consuming repeated analyses required by MCS. A training algorithm is implemented for training the NN utilizing available information generated from selected elasto-plastic analyses.

A NUMERICAL ESTIMATION OF THE INTERRELATION BETWEEN ACCELERATION PARAMETERS AND DAMAGE INDICATORS IN EARTHQUAKE ENGINEERING

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ABSTRACT

This paper describes numerically, in form of correlation coefficients, the interrelation between several seismic acceleration parameters and the overall behaviour of structures. The latter one is expressed in form of structural damage indices. As well known, earthquake accelerograms have inherent information which can be extracted either directly, like the peak ground acceleration (PGA) and the total duration, or indirectly using a computer supported analysis. The results of such an analysis can be classified in peak parameters (e.g. peak ground velocity (PGV), peak ground displacement (PGD)), in spectral parameters (e.g. response-, energy-, fourier-spectra) and in energy parameters (e.g. ARIAS intensity, HUSID diagram, strong motion duration (SMD), power $P_{0.9}$). The observation of building damages after severe earthquakes, as well as the numerical elaboration of structural systems, show a more or less interdependency between the above mentioned parameters and the structural response.

In the present paper, first the numerical evaluation of several seismic parameters is obtained. Next, a nonlinear dynamic analysis is carried out to provide the total damage status of the structure. The aim is to distinguish among the several parameters those, which have drastic affection to structural destruction. Further, the design philosophy of aseismic codes can be verified. The attention is focussed on earthquake acceleration time histories of worldwide known sites with strong seismic activity.

As the numerical results for a reinforced concrete structure have shown, the peak parameters provide poor or medium correlation to the overall structural damage indices (OSDI), while the spectral and energy parameters provide good correlation. Due to this reason, spectral and energy related parameters are better qualified to be used for the characterisation of the seismic damage potential. Finally, the design criteria of the EC2 and EC8 Eurocodes lead to satisfactory structural behaviour for seismic excitations, even the structural damage cannot be completely avoided.

NUMERICAL INVESTIGATION OF THE ROCKING RESPONSE OF ANCIENT COLUMNS AND COLONNADES UNDER HORIZONTAL FORCES

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ABSTRACT

Columns and colonnades (including free standing monolithic columns or columns with drums) is the typical structural form of ancient Greek or Roman temples. Models of such structures were studied both experimentally and numerically, by the Laboratory of Strength of Materials of the Aristotle University of Thessaloniki. This numerical study, which aims to predict the behavior of the single steel column and the various colonnade formations, when they are subjected to horizontal static pull-out forces, is the subject of this paper. The Finite Element Method was implemented and the models that have been examined numerically, were: a) A single column b) A two-column colonnade. Figure 1 shows the mesh employed, in this numerical simulation, for the two-column colonnade. The numerical analyses performed up to now were non-linear static analyses and were intended to simulate numerically the rocking response of the columns or colonnades that was observed during the experimental study.

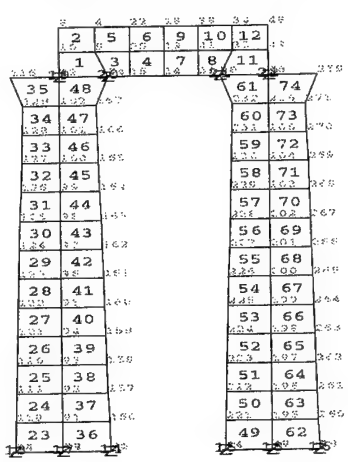

Figure 1. Finite element mesh employed in the numerical simulation

The numerical results, include the predictions of the behavior of the single column model and the two-column model colonnade formation, when they are subjected to horizontal static forces. Moreover, the presence of a certain intervention technique, employing shape memory alloy devices (SMAD's), was also incorporated in this numerical simulation. In this way, a simple attempt was made to numerically simulate both the contact problem, which is inherent in the behavior of the studied structural formations, as well as the presence of the SMAD's. The objective here was to be able to check if such a relatively simple numerical simulation could yield realistic results so that then it can be utilized in the framework of our research effort. Parametric studies were also performed in order to check the sensitivity of the solution to various parameters.

ELASTOPLASTIC RESPONSE SPECTRA FOR THE DESIGN OF STRUCTURES SUBJECTED TO EXPONENTIAL BLAST LOADING

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ABSTRACT

The objective of this paper is to investigate the response of structures subjected to blast loading and to propose tools for structural design under this loading condition. To that effect, a dynamic analysis for a single degree-of-freedom, non-dissipative system with elastic-perfectly plastic material behavior is presented in detail within the framework of a symbolic manipulation software. The equations of motion in every stage and cycle of the response are solved analytically and the solutions are combined to obtain the total response of the system. This analysis is then performed for blast loading simulated by triangular and exponential time functions, the first representing the common approximation and the second resembling to the real time distribution of explosive actions. The solution is performed for a wide range of ratios of load duration to fundamental period of the system and different ratios of load amplitude to system resistance. The results are presented in the form of response spectra plotting the ratios of maximum displacement to elastic displacement, as well as the times of occurrence of maximum response.

The spectra obtained for triangular load distribution are compared to similar ones from the U.S. Department of the Army Technical Manual, which are used today internationally for design purposes. Some differences are observed, attributed to the fact that the present analysis considers the case of obtaining the maximum response not in the first but in subsequent stages and cycles of the response, and is thus more accurate.

Then, the response spectra for the triangular and the exponential load distribution are compared. In most cases, the differences are not significant for design purposes, but regions of the design parameters are found, for which the response due to exponential blast loading is much lower than due to triangular one. This can have important design implications, as illustrated with an example.

ANALYTICAL ESTIMATION OF TOTAL DISPLACEMENT'S COMPONENTS OF R/C SHEAR WALLS WITH ASPECT RATIO 1.0-1.5 SUBJECTED TO SEISMIC LOADS

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ABSTRACT

Analytical approach for the determination of the components of totally imposed displacements at the top of R/C shear wall specimens is presented here. The matrix model which represents all possible deformation modes of the flat disc has been used and modified according to the assumed existing conditions for loaded discs. The load has been imposed by means of top horizontal cyclic forces. Examples for the application of this methodology on experimentally tested wall specimens are also presented here. Specimen were loaded by means of horizontal forces (imposed displacements) on the top until a 25% drop in strength. Measurements of purposely-located elongation meters were used for the application of that methodology mentioned. Useful conclusions result for the distribution of displacement components on flexural, shear and sliding shear mechanisms for each displacement-ductility level. Diagrams that arise when applying this methodology are also presented and indicate that sliding shear deformation mechanism becomes critical for shear walls with aspect ratio within 1.0-1.5.

COMPETITION AMONG GENETIC ALGORITHMS TO IMPROVE ROBUSTNESS IN OPTIMIZATION

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ABSTRACT

Genetic Algorithms are search algorithms based on the concepts of natural selection and survival of the fittest. They conduct an evolution of a set of randomly selected population of designs through a number of generations that are subjected to successive reproduction, crossover and mutation, based on the statistics of each generation. The efficiency of the whole process is problem dependent and relies heavily on the successful selection of the number of parameters that control the robustness of the algorithm, namely; population size, probability of crossover and probability of mutation. In this work a method is proposed that attempts to automate the tuning of these parameters in a robust way through an adaptive process, which is based on the competition of subgroups of the population, and in the mean time trying to reduce the overall processing time.

Competition, among different populations is common in natural systems. Populations evolve through their adaptation in the environment where resources are limited. By coupling GAs with a scheme of Competing Populations (CP) a number of subpopulations are produced in every generation, which evolve in the design space in an adaptive way by altering their parameters, i.e. population size, probability of crossover and probability of mutation. By reducing gradually the resources, the system organizes better its overall search strategy and manages to come up with very good near optimal solutions faster as compared to the standard GA. The relative capacity of a subpopulation to adapt to the artificial habitat is used to calculate the overall fitness at every instance. Competition arises when the resources are insufficient to sustain the entire population. Predator – Prey relationships are activated by assigning of conflicts among the subpopulations, where the predator subpopulation is trying to continue straggling for survival through the extinction (or drastic reduction) of its prey. The prize for the "predator" is the resources allocated for the "prey". These conflicts continue until a new point of equilibrium in the inter-population dynamics is found.

A number of problems in the form of benchmark tests, typical for Genetic Algorithms, are used and their results are presented. These include unimodal and multimodal functions and the proposed method proved to perform very satisfactorily as compared to a standard GA.

YUGOSLAV INVESTIGATIONS CONCERNING THE PATCH LOADING ON GIRDERS

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ABSTRACT

This paper describes Yugoslav experimental and theoretical investigations concerning behaviour of plate girders subjected to a localized edge load - i.e. patch load. Several aspects of this complex problem have been analyzed. In the first part of the paper local and overall stability of girders with long span is considered. In the case of local instability experimental evidence has shown conclusively that plastic hinges form in the loaded flange accompanied by yield lines in the web. The mode of failure and assumed collapse mechanism obtained by these tests are shown. The simple approximate solution based on this assumed collapse mechanism has been reduced to a simple closed form. The investigation of overall instability presents behaviour of slender plate girders which are susceptible to combined local and lateral (or distortional) instability. It is shown that classical buckling solution is not adequate to predict the behaviour of such girders which failed in distortional mode. In the second part of the paper stocky and slender plate girders with short span are considered. For the centrically loaded girders a new mathematical procedure for the determination of the collapse load is proposed based on the experimental evidence. Experimental research of the slender plate girders subjected to loading with certain eccentricity with respect to the web panel is also presented. The collapse mode of eccentrically loaded girders is obtained significantly different than for the centrically loaded girders. In the third part the analysis of the ultimate load behaviour of plate girders with longitudinal stiffeners subjected to a patch load is presented taking into account especially the influence of the length of the patch load. A simple form for taking into account the influence of longitudinal stiffeners is suggested.

SYNTHESIS OF NEW PHENOLIC POLYMERS VIA ENZYMATIC POLYMERIZATION AND THEIR PROPERTIES

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ABSTRACT

We have recently found that oxidoreductase enzymes catalyze the oxidative polymerization of phenol and its derivatives by using hydrogen peroxide or air(oxygen molecules) as an oxidizing agent. A horseradish peroxidase (HRP) -catalyzed polymerization of phenol itself gave polyphenol with controlled structure as well as molecular weight. The polyphenol is soluble in an organic solvent and can be regarded as a real polyphenol, in contrast to the conventional commercial phenol resins which contains toxic formaldehyde component.

"Urushi" is a typical Japanese traditional coating showing excellent toughness and brilliance for a long period, even longer than one thousand years. It was revealed in the early of the 20th century that the main component of urushi is "urushiol", which is a catechol derivative with unsaturated hydrocarbon chains having a mixture of monoenes, dienes, and trienes at 3- or 4-position of catechol. Urushi is formed via the oxidative crosslinking reaction of urushiol in air catalyzed by laccase enzyme. For the preparation of urushi, a multi-step, tedious synthesis of urushiol is required, which is too much work. Therefore, we designed new urushiol analogues, which can be prepared by a lipase-catalyzed single-step reaction. The urushiol analogues were crosslinked catalyzed by laccase in air to give "artificial urushi" whose properties were comparable with those of natural urushi. Another type of artificial urushi and polycardanol (also an artificial urushi) from cardanol were obtained similarly via crosslinking in air.

Tyrosinase is a mono-oxygenase of phenolic compounds to o-quinones in vivo. We have found a tyrosinase model complex catalyzes the oxidation polymerization of ortho-unsubstituted phenols in vitro to poly(phenylene oxide)s, in which a regio-selective reaction took place to control the 1,4-structure. A similar regio-selective polymerization of 2,5-dimethylphenol was induced by the same catalyst to produce crystalline poly(2,5-dimethyl-1,4-phenylene oxide), whose melting point was >300 ^{0}C, being high enough as a super-engineering plastics.

ADAPTIVE FINITE ELEMENT ANALYSIS OF LIMIT-LOAD STATES IN DRY AND SATURATED SOILS

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ABSTRACT

The presentation deals with the finite element analysis of strain localization in dry and water saturated soils. After a review of different regularization techniques which are necessary to avoid spurious mesh dependencies a Cosserat formulation is discussed in more detail. In addition, the Theory of Porous Media is used to extend the application to saturated geomaterials with coupled deformation and fluid flow and leading to a second regularizing effect.

Shearbands connected to the limit-load state of the system are formed quite rapidly in time and further deformation is restricted to distinct narrow zones characterizing the type of failure. Therefore, the accuracy of the finite element solution is governed by the small mesh size in the zone of localization and reasonable time step sizes. To capture the forming of the shearband adaptive methods in space and time are applied using a hierarchical mesh refinement and an automatic time step adjustment.

The adaptive strategies are based on a combination of four different error indicators. Two of them control the space adaptive part and provide a measure for the spatial discretization error by evaluating the residuum of the extended equilibrium conditions and the error in the continuity of the fluid flows. They are employed in the formulation of the Cosserat continuum and the transport subproblem. The time adaptive part includes indicators for the temporal discretization error and for the error in the numerical integration of the constitutive equations.

The numerical examples (e.g. a strip footing on half space) show that reasonable discretizations may be achieved improving the efficiency of the solution technique. Localization phenomena are detected and refined properly. Additionally, the step sizes are consequently reduced when the formation of shearbands is initiated. The limit-loads obtained by this approach are shown to be realistic and are compared to the results obtained by classical approximate methods.

MEASUREMENT OF THE MECHANICAL PROPERTIES OF MEMS MATERIALS

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ABSTRACT

MEMS, or microelectromechanical systems, are tiny sensors and actuators manufactured by processes similar to those of the microelectronics industry. Typical products are accelerometers for automobile airbags and disposable pressure sensors for medical use. The actual microdevices may be as small as a few tens of micrometers in length or width and a few micrometers in thickness. The materials commonly used – polycrystalline silicon, silicon nitride, single crystal silicon, various metals – are familiar as electrical materials in the microelectronics industry but are now used as structural materials in MEMS. They are actually new materials because the manufacturing processes are very different from those used to produce common bulk materials.

The elastic, inelastic, and fracture properties of these materials must obviously be known for intelligent mechanical design and life prediction. However, measurement of these properties is not so easy; one does not simply cut out a specimen and mount it in a test machine. The main issues associated with mechanical testing of MEMS materials are the preparation and handling of the specimen, application and measurement of force, and direct or indirect measurement of strain.

The author and his colleagues have developed techniques and procedures for tensile testing of thin-film specimens as small as 1.5 x 5 x 250 micrometers in thickness, width and length. (Human hair is 80-120 micrometers in diameter.) Larger specimens, with dimensions of 200 x 500 x 2000 micrometers, are also tested. This paper reviews other test methods, describes the current tensile test methods, and presents results for polycrystalline silicon, silicon nitride, silicon carbide, and electroplated nickel. In general, the elastic properties are similar to those of the equivalent bulk material, but the strengths may be considerably larger.

BEHAVIOR OF PARTICLE REINFORCED COMPOSITES WITH SOFT MATRICES

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ABSTRACT

The behavior of a matrix reinforced by particles depends on the adhesion between the particles and the matrix. The damage that the material experiences as the material is loaded manifest itself as separation between the matrix and the particles. In the present work a theoretical; experimental and numerical analysis of the interaction between matrix and particle is presented. Two different procedures, one microscopic, and the other macroscopic measure the progressive damage of the composite. Excellent agreement is found between them. Numerical results obtained from finite element analysis provide a confirmation of the experimental results. At the same time through the numerical results it is possible to explain the observed behavior of the composite.

INDENTATION FAILURE OF SANDWICH PANELS

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ABSTRACT

Indentation failure under the load is a predominant failure mode of sandwich construction in cases where the applied load is distributed over a small area. Under such circumstances, significant local deformation of the loaded facing into the core of the sandwich construction takes place causing high local stress concentrations. The problem is modeled as an elastic beam resting on a Winkler foundation. The stress field is obtained by superimposing the global bending of the sandwich construction due to the global bending and shearing and the local bending of the loaded face sheet about its own neutral axis.

A combined analytical and experimental investigation was undertaken. Two cases were studied, a sandwich panel with carbon/epoxy facing and a PVC foam core supported on a rigid base and indented at mid-length with a cylindrical indenter and a sandwich beam with symmetrical facings and core materials as in the sandwich panels. In the latter case global bending effects are taken into account. The load-deflection behavior of the loaded facing was monitored during the test. In the case of the beam, the indentation of the loaded face was obtained as the difference between the displacements of the upper and lower faces of the beam. A full-field analysis of the in-plane displacements and stresses in the foam was undertaken using moire and birefringent coating methods.

The problem was modeled as an elastic beam resting on an elastic-plastic foundation. Initiation of indentation failure occurs when the foundation yields. Yielding of the foundation which is made of a PVC closed-cell foam with anisotropic behavior was described by the Tsai-Wu failure criterion. Following failure initiation under a progressively increasing applied load the plastic zone in the foam increases up to a limiting point at which fracture of the compression facing occurs. For the sandwich beam this takes place when the sum of the global and local compressive stresses becomes equal to the facing compressive strength. The local compressive stress was calculated from the elastic beam resting on an elastic-plastic Winkler foundation, while the global compressive stress is the overall beam stress at the facing. The local indentation causes the lower surface of the facing to have a tensile longitudinal stress which is much higher than the global compressive stress. The longitudinal strain developed at this point of the beam was measured by a strain gage embedded at the interface between the facing and the core.

The moire fringe patterns corresponding to the horizontal and vertical displacements of the foam were recorded for a progressively increasing applied load. Similarly, the isochromatic fringe patterns obtained from the birefringent coatings were recorded during the test. From

these patterns the state of deformation and stress in the core were determined. The evolution of the plastic zone in the core from initiation of failure up to compressive failure of the loaded facing was calculated. The experimental results were in good agreement with results of the analytical modeling based on the Winkler foundation.

INDENTATION FAILURE OF A PVC CELLULAR FOAM

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ABSTRACT

Cellular foams are frequently used as core materials in sandwich construction. They are relatively inexpensive and consist of a vast variety of foamed plastics and metals with varying density, properties and strength. Commercially available plastic foams are made of polyvinyl chloride (PVC), Polyurethane (PUR), and polystyrene, among others. Metallic foams are usually made of aluminum. The properties of foams depend on the structure of the cell, the density and the material of which they are made. A detailed characterization of their mechanical behavior is essential for their efficient use in structural applications.

In the present work the indentation failure of two types of a PVC closed-cell cellular foam under the commercial name Divinycell H100 and H250 was studied. The stress-strain curve in uniaxial compression of both materials consists of an initial linear portion followed by a nonlinear part and a yield region in which the stress remains essentially constant. After the termination of the yield region the stress increases sharply corresponding to material densification. Divinycell H100 displays nearly isotropic behavior, while Divinycell H250 is strongly axially anisotropic. The modulus of elasticity and strength of H250 along the through-the-thickness are much higher than along the in-plane direction. Furthermore, the modulus of elasticity of both Divinycell H100 and H250 in tension and compression are almost equal, while the tensile strength is much higher than the compressive strength. The failure behavior of both materials can be predicted by the Tsai-Wu failure criterion.

A rectangular plate indented by a smooth rigid cylindrical indenter was analyzed. The stress and deformation fields were obtained by the ABACUS computer code. The results of the stress analysis were combined with the Tsai-Wu failure criterion to study the failure behavior of the foam plate. The load-displacement behavior was recorded experimentally and compared with the analytical predictions. It consists of an initial linear part followed by a nonlinear behavior. The failure mechanisms of the plate were studied experimentally and predicted by theory.

ESTIMATION OF THE CONCRETE CHARACTERISTICS USING PATTERN RECOGNITION METHODS

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ABSTRACT

We address the problem of non-destructive analysis and testing of concrete. The proposed system employs acoustic emission and pattern recognition of the corresponding signals to identify the characteristics of a given concrete cube. A series of experiments was conducted using concrete cubes with known characteristics to construct a database with typical cases (examples). These examples are then used for the development of the pattern recognition system (data –driven approach).

The concrete characteristics of interest that must be estimated by the pattern recognition system are: i) the age of the item, ii) the water to cement ration, iii) the sand to cement ratio. Through experimentation we have also identified a set of characteristic features that best describe the original waveform obtained at the receiver. In this work, based on experimentally collected example cases, we attempt to construct a pattern recognition system that will use the waveform features to estimate the water to cement ratio (W/C) and sand to cement ratio (S/C) for concrete items of specific age.

Several classification methods are employed to tackle the problem. More specifically, we considered two neural network techniques, based on the multiplayer perception and the radial basis functions network. Also we applied a classical non-parametric method, the k-nearest neighbor as well as a statistical pattern recognition method, based on probability density estimation and the Bayes decision rule. In this work, we provide comparative results from the application of the above four pattern recognition methods, identify the most promising methods and present estimation results which are very encouraging.

DESTRUCTIVE AND ULTRASONIC NON-DESTRUCTIVE TESTING OF 28-DAY AND 28-YEAR OLD CONCRETE

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ABSTRACT

The purpose of this experimental work is the examination of 28 years old concrete, using destructive as well as non-destructive testing methods. The specimens used were made from 28 years ago, when the study for the behavior of concrete in multiaxial loading took place, in order to be constructed the failure envelope of this material [1, 2]. A number of specimens (cylinders, cubes and prismatic bars) were preserved carefully in a humidity chamber with a relative humidity of 80% and a temperature of 20°C until today. The destructive tests consisted from the simple compression test of cylindrical and cubic specimens, the splitting test of cylindrical specimens and the simple bending test of prismatic specimens. The results were compared with those, which revealed from the initial experiments and appeared in the papers [1, 2, 3] and are presented together with them in this paper in order to be clear the change of the mechanical properties of the concrete during this time period of 28 years.

On the other hand the used concrete specimens, before their fracture, were tested using the non-destructive testing method of ultrasounds, (in order to reveal the possibility of its examination by this method). So by the application of the NDT method of ultrasounds, first the exact dimensions of the concrete specimens were computed, then the velocity of longitudinal ultrasonic elastic waves and through them the elastic modulus of elasticity E and furthermore the fracture stress σ_f were evaluated.

Interesting and novel conclusions are revealed for the quality of this aged concrete, as well as for the ability of the NDT method of ultrasounds for the quality characterization of the concrete and consequently the constructions made from this material.

References:

1. Theocaris P.S. and Prassianakis I., A study of concrete under multiaxial loading, Technika Chronika, T.C.G., p.p. 293-302, April 1974.
2. Theocaris P.S. and Prassianakis, The Mohr envelope of failure for concrete: a study of its tension-compression part, Magazine of Concrete Research, Vol. 26, No 87, pp. 73-82, June 1974.
3. Prassianakis I.N. and Gkiokas P., The NDT of concrete using Ultrasounds 2nd National Conference of HSNT, Volos 17-6-2000, Proc. Pp. 101-108, HSNT.
4. Krautkramer J. and Krautkramer H., Ultrasonic Testing of Materials, Springer-Verlag, Berlin (1977).

5. ASTM, STP 1045 , Dynamic Elastic Modulus Measurements in Materials, A. Wolfenden, Ed., ASTM, Philadelphia, PA 19103.
6. R. Jones, I. Făcăoaru, ''Recommendations for testing concrete by the ultrasonic pulse method'', Matériaux et Constructions, Vol. 2, N° 10, 1969, pp.275-284.
7. D. Mikulić, Ž. Pauše, V. Ukrainčik, ''Determination of concrete quality in a structure by combination of destructive and non-destructive methods'', Materials and Structures, 25, 1992, pp. 65-69.
8. A.P. Ferreira, P.F. Castro, ''Application of NDT to Concrete Strength Estimation'', International Symposium on NDT Contribution to the Infrastructure Safety Systems, 1999, Nov 22-26, Torres.

EXPERIMENTAL QUANTIFICATION OF CRACK TIP PARAMETERS FOR PARTICULATE METAL MATRIX COMPOSITES

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ABSTRACT

The validity of the HRR model for cracked Metal Matrix Composite (MMC) specimens is investigated by experimentally quantifying a number of crack tip parameters. Such a quantification is an important task in Elastic Plastic Fracture Mechanics (EPFM), since the loss of constraint occurring with large scale yielding is directly related to the deviation of the relationship between the J-Integral and the Crack Tip Opening Displacement (CTOD or δ_t) from the one given by Shih [1]:

$$J = \frac{\sigma_0 \delta_t}{d_n} \tag{1}$$

This relationship was obtained by Shih [1] using the HRR solution according to which the stress field, σ_{ij}, for a power law idealization of the flow behaviour of the material (Eq.2a), in case of generalized deformation theory of plasticity, are described by the following equation 2b:

$$\varepsilon_{ij} = \frac{3}{2}\alpha\left(\frac{\sigma_e}{\sigma_0}\right)^{n-1}\frac{S_{ij}}{E} \quad \text{(2a)}, \qquad \sigma_{ij} = \sigma_0\left(\frac{EJ}{\alpha\sigma_0^2 I_n r}\right)^{1/(n+1)}\tilde{\sigma}_{ij}(n,\theta) \quad \text{(2b)}$$

(σ_e is the effective stress, S_{ij} the deviatoric stress, σ_0 a reference stress [2], E is Young's modulus, r the radial distance from the tip, I_n a dimensionless constant depending on strain hardening, σ_{ij} a dimensionless constant depending on strain hardening and θ, and (α, n) experimentally defined constants). Concerning the function d_n=d_n(n, ε_0), given by Shih as a nomogramme, Omidvar et al. [3] theory, was adopted:

$$d_n(n,\varepsilon_0) = \varepsilon_0^{\,1.05/(n-0.1)}\left(1+\frac{3}{n}\right) \tag{3}$$

The previous analysis is valid as long as each material point experiences proportional loading. For cracked bodies, however, this is not the case, since an intense strain region exists, within ~2δ_t of the tip, that experiences highly non-proportional loading. In this case the analysis is only valid if the intense strain region is surrounded by a region in which the HRR model assumptions still prevail. This is true as long as δ_t is small compared to both the crack

size and the uncracked ligament length. Else fracture toughness becomes geometry dependent [4].

The above assumptions were investigated with the aid of a series of experiments which were carried out using single edge notched specimens for the quantification of the intense strain zone and the CTOD for various ratios, f, of the crack length to specimen width. These parameters were estimated with the aid of Scanning Electron Microscopy, permitting determination, on a micro-scale level, of the intensively damaged area around the tip, as well as the evolution of the CTOD, the Crack Tip Advanced Displace-ment, the shape of the plastic zone and relevant micro-failure phenomena around the SiC particles, used as reinforcement in the case of the 2124 Al-Cu particulate MMC studied in the present work..

It was concluded that the conditions necessary for the HRR analysis to be valid are not violated for a wide range of f values. This behaviour can be explained, since the analysis of the SEM images pointed out that the fracture processes in the case of particulate reinforced MMCs are significantly influenced by the presence of particles, even if they are in the form of platelets, and, also, that void nucleation than void coalescence is the critical step for failure. Voids are formed when the local stresses exceed the stress necessary to decompose the particle. When the local plastic relaxation, that relieves stress concentration becomes difficult, as in case of pre-cracked materials, where it is concentrated in the vicinity of the tip of the macroscopic crack, then the final failure occurs at rather low strains.

References:

[1] Shih, C. F., Journal of the mechanics and Physics of Solids **29** (1981) 305-326

[2] Anderson, T. L., International Journal of Fracture **41** (1989) 79-104.

[3] Omidvar, B. Wnuk, M.P. and Choroszynski, M., International Journal of Fracture **87** (1997) 331-343.

[4] Schapery, R. A., Technical Report MM5762-88-1, Texas A&M University, College Station TX, 1988.

ON SELECTING A COMPATIBLE SUBSTITUTE FOR THE KENHCREAE POROS STONE USED IN THE EPIDAUREAN ASKLEPIEION

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ABSTRACT

The mechanical behaviour of the Kenchreae poros stone, that has been used in building the upper-structure of various monuments in the Asklepieion of Epidauros, is investigated in the present work. It is compared to that of 3 other porous stones (Alfopetra of Crete, Zakynthos poros stone and Cyprus poros stone) of different cohesion that have been proposed as possible suitable substitutes.

The first part presents experimental results from testing both ancient material, exposed for 2500 years to natural weathering and recent drill cores from the region of the ancient quarries. The speci-mens were tested either in their natural condition or after being submitted to accelerated artificial weathering since recent research indicated relation between the observed strength and the past load-ing and weathering conditions of the material tested [1]. The effect of weathering on the mechanical properties of the material is studied by testing specimens previously subjected to freeze-thaw cycles.

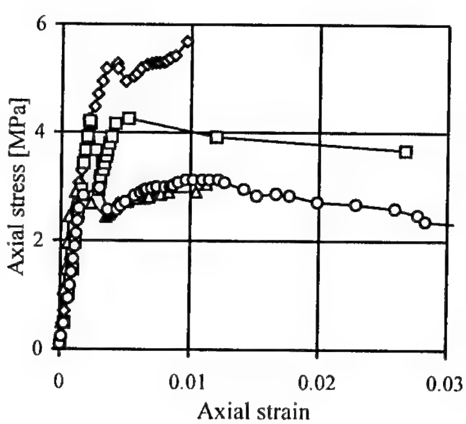

Figure 1 : Typical examples of stress-strain curves for Kenchreae poros stone.

In general, Kenchreae poros stone shows an atypical stress-strain diagram, consisting of an initial quasi-linear elastic part of almost constant slope, followed by an abrupt drop in strength after which the material recovers to different degree, depending on the meso- and macro-structural features of the particular speci-men, reaching then an almost horizontal (or smoothly dropping) plateau, where it remains until the final generalized fracturing, as shown in Figure 1 [2]. This behaviour, clearly attributed to the specific conditions of geological formation, is further investigated by opti-cal and electron microscopy analysis of the specimens at various stages of the loading procedure. An attempt is made to correlate the level of loading with the damage coefficient [3]. The influence of the end pla-ten friction on the failure load and mode of friction was examined by conducting a series of tests with pla-tens made of the same material as that of the specimens.

As the choice of a substitute stone is a crucial factor in the passive protection of the ancient material incorporated in the restoration of a monument, in the second part of the investigation a number of tests were carried out on composite specimens, consisting of newly quarried or drilled Kenchreae poros stone and substitute stones. The resulting changes in the stress-strain relationship are examined and discussed. The influence on the curve of a number of parameters such as the relative size of the patch and its position in the specimen, the shape and inclination of the interface of the two materials, and the strength of the bonding mortar is also examined.

References

[1] Vardoulakis I., Kourkoulis S.K. and Zambas C., Modeling of the mechanical behaviour of con-chyliates shellstone, *2nd Int. Symposium on Hard Soils Soft Rocks*, Naples, Italy. A. Evangelista and L. Picarelli Eds., Balkema, 911-922, 1998.

[2] Kourkoulis S.K., Vardoulakis I. and Ninis N., Evaluation and theoretical interpretation of mechani-cal properties of porolithoi used in the restoration of the Epidaurean Asklepieion, *Int. Conf. on Geology and Geotechnics in the Preservation of Historical and Cultural Heritage,* Tourin, Italy. In press, 2000.

[3] Prassianakis, I., Kourkoulis, S.K., Vardoulakis, I. and Exadaktylos, G., Non-destructive damage characterization of marble subjected to bending, *2nd Int. Conf. on Emerging Technologies in NDT*, Athens, Greece. D. Hemelrijck, A. Anastassopoulos and T. Philippidis Eds., Balkema, pp. 117-124, 2000.

FORMAL METHODS TO DESIGN COMPOSITE SHELLS FOR ROBUSTNESS AND AFFORDABILITY

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ABSTRACT

Composite shells are used in many applications, such as underground and aboveground storage, transportation vehicles, marine hulls, airplane fuselages and wings, space vehicle boosters, helicopter and windmill blades. These shells are mostly fabricated by filament winding on either hard mandrels or on thin liners with progressively increasing internal pressures. The pressure counter acts the build-up pressure developed by the increasing winding wrap thickness. The resulting wall laminate thickness has a residual stress field which is a combination of the filament winding and curing processes. The residual stress fields are combined with those from the operating loading conditions to evolve candidate designs. These designs are subsequently evaluated by various mechanics methods for durability, damage tolerance and reliability in order to select a robust design. Lastly, the robust design is comparatively evaluated for cost in order to obtain an affordable design. The objective of this invited paper is to describe a formal process that can be used to obtain robust designs, and a procedure is outlined which can be used to obtain affordable designs. It is applied to evolve affordable designs for three different composite shell structures in order to demonstrate the effectiveness/versatility of that formal process. Results from three different composite shell structures (fuselage, underground tank and a windmill blade section) show that robust and affordable designs can be obtained from that formal process.

STRESS CONCENTRATION AND MATRIX CRACK GROWTH CHARACTERISTICS IN COMPOSITE LAMINATES

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ABSTRACT

One of the major problems in damage tolerance design with composite laminates is the accurate prediction of damage, which can lead to solid conclusions as regards the fracture path in a structural component. The initial mode of damage in multidirectional composites has been observed to be the accumulation of matrix cracks in the off–axis plies. This kind of damage develops until reaching a so-called saturation point. Several other damage modes, such as delamination, may appear concurrently or just upon termination of the matrix cracking process, due to joining and growth of these cracks.

Remote Laser Raman Spectroscopy (ReRaM) has been employed to monitor the local strains in cracked cross–ply composites. The experiment involves the incorporation of an aramid (Kevlar 49®) fibre into the 0° ply and near the 0°/θ° interface of glass – fibre reinforced epoxy resin laminates which is interrogated with the laser Raman probe. This type of laminate is transparent due to the matching of the refractive indices of glass fibres and epoxy resin. Thus, the changes in the longitudinal strain in the 0° ply, caused by transverse cracking in the θ° ply, are quantified. Important parameters such as the magnitude of the strain magnification as a function of geometrical characteristics are derived.

In this work, the results obtained on $[0/90/0]_t$ and $[0/45/0]_t$ laminates that have been produced under identical conditions, are reported. The strain magnification in the 0° ply caused by 90° or 45° cracking are measured at different levels of loading. The achievement of "quasi" - stable crack growth conditions resulted in strain magnification values due to various crack lengths. A relationship between the values of strain magnification and the distance between the fibre and the 0°/θ° interface has been derived. Thus, important conclusions concerning the mechanisms of strain transfer as well as the conditions of crack growth and crack – crack interaction are drawn from this work.

NON-LINEAR MECHANICS AND BUCKLING ANALYSIS OF COMPOSITE SHELLS WITH EMBEDDED PIEZOELECTRIC ACTUATORS AND SENSORS

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ABSTRACT

During the recent years the study of composite materials and analysis of smart/adaptive structures has received substantial attention. A significant part of this effort has been directed towards the development of piezoelectric composites, that is, composites with embedded piezoelectric actuators and sensors. Most of the work which has been reported so far, has been focused on the static and dynamic response of smart structures and has been limited to the linear region. It seems that the inclusion of geometrically nonlinear effects in the mechanics and the application to buckling analysis has not been considered. Consequently, the present paper will present the development nonlinear mechanics for smart piezoelectric composite shells and resultant finite element based formulations for solving the initial stability problem of piezoelectric shells.

Approach

The proposed model is based on the so called mixed-field piezoelectric shell theory, developed by the authors, which combines single layer kinematic assumptions for the displacements and layerwise assumptions for the electric potential through- the-thickness of the laminated shell. The previous theory is extended to include nonlinear terms as a result of large displacements and rotations. The analysis assumes small and linear constitutive equations. The governing equations are defined in generalized global curvilinear coordinates and are valid for shallow shells. The mechanics is unique, because it includes the coupling between mechanical and electrical fields, and most importantly, with geometric nonlinearity.

A finite element formulation is also developed encompassing the previous nonlinear shell mechanics. An eight node shell finite element is formulated which captures the new nonlinear structural and piezoelectric terms in the form of an initial stress and nonlinear element matrices. The problem of initial stability is further formulated and solved. The terms of the initial stress matrix depend on external mechanical loads and applied electric voltage. Nonlinear matrices were developed for both structural stiffness and piezoelectric terms. The formulation of the initial buckling problem enables prediction of mechanical buckling and the associated critical mechanical loads, and/or piezoelectric buckling caused by the application of critical electric fields on the piezoelectric layers. Moreover, the method enables the prediction of buckling compensation through the application of suitable electric voltage on the actuators.

Expected results

Numerical results will be presented evaluating the developed mechanics and the capabilities of the proposed model. The case studies will address:

1. The buckling of laminated plates and cylindrical shells under mechanical load. Predictions of buckling modes and the corresponding sensory voltages at embedded piezoelectric sensors will be also shown.
2. The buckling of laminated plates and shells under applied electrical fields on the piezoelectric actuators, and
3. The active compensation of mechanical buckling in laminated plates and shells using piezoelectric actuators.

A NEW DESIGN METHODOLOGY FOR HIGH TEMPERATURE STRUCTURAL COMPONENTS MADE OF CONTINUOUS FIBER CERAMIC COMPOSITES EXHIBITING THERMALLY INDUCED ANISOTROPIC DAMAGE

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ABSTRACT

Continuous Fiber Ceramic (Matrix) Composites (CFCCs) have found during the last decade numerous industrial applications in a variety of technological areas, where structural components are subjected to high temperature combined with significant mechanical loading. Among them, aero-engine turbine discs, blades, liners and combustor chambers, low-pressure gas turbine nozzles, thermal protection blankets for re-entry vehicles, automotive gas turbines, brake discs in transport applications are typical examples.

The basic parameter which supports the use of CFCCs in high temperature engineering components is their improved fracture toughness, compared to the monolithic ceramics, due to the activation into the material structure of various stress redistribution mechanisms. Thus CFCCs have the ability to withstand the initial damage without immediate catastrophic rupture.

The present work deals with the application of innovative design methodologies for the development of an industrial gas turbine combustor chamber made of oxide/oxide composite materials.

Oxide/oxide composites offer high-temperature structural stability without the need of any kind of oxidation protection and thus permit the increase of working temperature of the gas turbines, increasing the efficiency of the system and decreasing the need for cooling air and the NO_x emissions.

However, in the long run oxide/oxide composites appear a reduction of their structural performance as a function of working temperature and the duration of high temperature exposure, for temperature higher than 1000° C.
The design procedure involves:

- a completely new design of the combustor chamber which makes use of the material capacity and takes into consideration the manufacturing limitations
- the thermal analysis of the component and the calculation of the temperature profiles
- the structural analysis of the system, using the appropriate loading and boundary conditions.

At this preliminary phase, operational life of 1500 h duration is demanded for the combustor chamber.

Since, oxide/oxide composites appear degradation of their structural properties, an incremental approach has been introduced for the solution of the problem and each increment represents a thermal exposure stage. The structure has been divided in temperature zones and a mean working temperature was considered for each zone. During each time increment the material properties were considered constant and they change during the successive increments.

For the analysis of the problem the commercially available FE method was used. The data set required for the application of the above-described approach were obtained through an extensive material characterization program. The material characterization process involves typical quasi-static tests and an extensive set of 'stop and go' thermal fatigue experiments of the oxide/oxide composite at different temperature levels. At each stage of the thermal fatigue experiments advanced ultrasonic measurements of the composite stiffness matrix was conducted. Then, all the elements of the stiffness matrix of oxide/oxide composite are known functions of the applied temperature and the thermal exposure duration.

The final design of the combustor chamber made of oxide/oxide composites was compared against the conventional design of the same combustor chamber when metals are in use and the results are discussed analytically.

EXPERIMENTAL AND THEORETICAL STRESS ANALYSIS OF INCOMPRESSIBLE BONDED ELASTOMERIC DISCS SUBJECTED TO COMPRESSION

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ABSTRACT

The importance to understand the micro-fracture process, reinforcement, adhesive joint strength and explosive decompression in rubbers, extensive experimental studies were contacted previously by the author using the Acoustic Emission Technique. Various theoretical approaches to evaluating the stress and displacement field throughout bonded elastomer discs subjected to uniform tension and/or compression were adduced by Blatz and kakavas . An effective material property, ν_{eff}, was derived which is consistent with the measured values of the normalized volumetric contraction, $\gamma = -u_0(a)/a\varepsilon$ and the initial modulus from the triaxial tests on compression and tension.

The geometry of the testing samples were bonded circular discs the so-called *'poker chip'*, where their chemical composition was described in previous articles published by the author and coworkers. Analytical expressions for the axial stress in bonded elastomer discs subjected to triaxial stress were derived in the past using a neo-Hookean strain energy function and an algebraic equation was developed to correlate the diametrical contraction of the testing 'poker chip' samples with the applied strain. A theoretical equation of the nominal stress based on the average value of the axial component of stress was also developed and the derived numerical values were compared with the experimental data .

Finite element analysis has also been performed to examined the stress distribution in rubber bonded discs using the package ANSYS . Shariff in his late articles for solving boundary-value problems associated with nonlinear static deformation of slightly compressible materials developed a finite element method, which is attractive in the sense that only linear equations are to be solved for nonlinear boundary-value problems.

In the case, of compressible and/or incompressible solids significant theoretical progress has been made on the behavior of the force deflection relationship. Petrie and M. Shariff have given explicit solutions for nonlinear axisymmetric strain for bonded circular discs and plane strain for bonded rectangular blocks. In their analysis the bonded discs and/or rectangular blocks were constraint at the opposite faces by rigid plates against which any slip is prevented. The application of forces was normal to the end plates as it was applied in our experimental work.

In the present paper, after the introduction of basic equations of nonlinear rubber elasticity, the deformation gradient tensor $\mathbf{F}$, was developed for incompressible bonded circular discs subjected to uniaxial compression along the axial direction. The axial components of the Piolla stress was derived for *'poker chip'* type of samples by assuming that the material is incompressible and a neo-Hookean strain energy function was assumed for the derivation of the stresses.

The aim of the present article is to derive the distribution of stress and strain in bonded rubber discs subjected to uniaxial compression in axial direction. The axial stress was analytically computed using a neo-Hookean strain energy function. Assuming that the testing material is hyperelastic and incompressible the equilibrium equations leads to the solution of two separate ordinary differential equations, Their solution yields the radial coordinate and the pressure as a function of the axial coordinate within the compressed sample. Using the condition that the free surface, of the cylindrical samples subjected to uniform compression, is stress free, the undetermined constant in the pressure term was determined explicitly. The axial stress was also determined using the equilibrium equations of the deformed material and taken its mean value along the radial direction. The theoretical predicted axial stress was compared to the experimental data.

P-WAVE VELOCITIES FOR ORGANIZING THE SURFACE PROTECTION OF STONES. EXAMPLES FROM GREECE

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ABSTRACT

The P-wave velocities can be used for the estimation of the depth (D) of weathered or artificially consolidated layers as well as the depth of cracks at the surface of stones. This technique can be applied in the protection of both geological and cultural heritage.

The depth of weathering at a stone surface can be evaluated using the indirect ultrasonic velocity technique. In this case the transmitter is placed on a suitable point of the surface and the receiver is placed on the same surface at successive positions along a specific line. The transit time is plotted in relation to the distance between the centres of the transducers. A change of slope in the plot could indicate that the pulse velocity near the surface is much lower than it is deeper down in the rock. This layer of inferior quality could arise as a result of weathering.

The above mentioned technique could not only be performed for investigating the damage depth at the surface of stones but also for evaluating the effectiveness of this method for estimating the consolidation depth at the stones, after treatment. For this purpose, the above mentioned methodology was performed on the walls of the Medieval City of Rhode Island (Greece, Figs. 1, 2, 4, 5) as well as in Delos island (Figs. 3, 6) providing data for the effectiveness of the consolidation treatment on the walls.


Fig.1 *The moat around the medieval city of Rhode (tests of Fig. 4 & 5)*

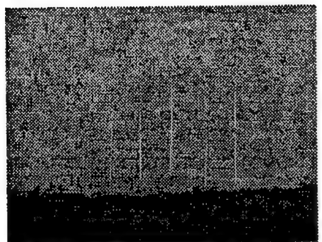
Fig.2 *Detail of the wall at the moat of the medieval city of Rhode (tests of Fig. 4 & 5)*


Fig.3 *Gaios Ophelios statue, in Delos island (Greece, Tests of Fig. 6)*

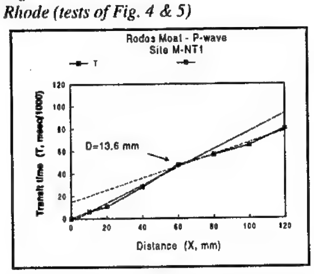

Fig.4 P-wave velocities measured on untreated surface of calcarenitic blocks (Moat around the medieval city of Rhode). The change of the regression slope corresponds to the depth of the weathered zone.

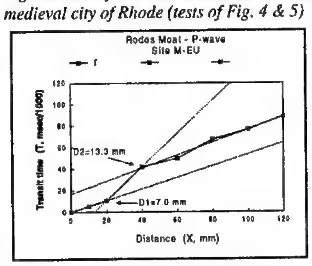

Fig.5 P-wave velocities measured on the surface of calcarenite blocks, treated with consolidation liquid (Moat around the medieval city of Rhode). The change of the regression slope corresponds to both consolidation and weathering depths

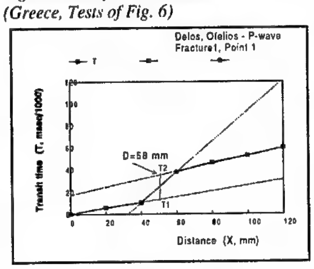

Fig.6 P-wave velocities diagram on the surface of Ophelios marble statue (Delos Island, Greece) for estimating the depth of a crack along its left leg.

OPTICAL DEVICE FOR PROSTATE CANCER DETECTION

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ABSTRACT

Prostate cancer is the most prevalent male cancer. The existing testing methods are subjective and not quantitative (Digital Rectal Examination) or not sufficiently accurate or expensive (ultrasound, biopsy). There is a need for a simple, yet accurate method to detect changes in the mechanical properties of the prostate as a replacement of the DRE. We developed a new device, which is able for geometric representation and objective measurements of the stiffness of the prostate tissue, based on image processing of data taken with a micro camera from an inflated balloon inserted in the rectal area and touching the prostate.

Computer based digital image processing applied consists of: transformation of image data (captured by micro camera) to intensity matrix, image enhancement (contrast, brightness), block processing and relative distance calculation (shape from shading method), calculation of relative stiffness value corresponding to each block and objective data mapping (containing geometric representation of the prostate, calculation of prostate area and stiffness map). For this purpose a genuine algorithm was developed.

The research prototype built was successfully applied to models for prostate diseases and cadaveric tissues for preliminary assessment. The results encouraged the first clinical application in vivo, which has demonstrated that there were no side effects mentioned by the doctors or the subjects examined. The reproduction of the stiffness map enables the assessment of the changes in mechanical properties of each prostate surface. In all cases, results can be compared and are in agreement with the results of conventional methods (DRE, ultrasound). Hence the proposed design is feasible and can lead to a diagnostic tool. This design will be used to validate in clinical setting the sensitivity and specificity of the device developed.

EXPERIMENTAL VERIFICATION OF SHEAR WALL MODELING USING FINITE ELEMENT ANALYSIS

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ABSTRACT

The objective of this study is to investigate the most adequate way of modeling the shear walls of a 3D building. A building from elastic material is modeled using Lexan and we examine its behavior under an external static force. Using the photoelastic method we inspect the stresses at shear walls and the experimental results are compared with the corresponding results of a computational model by finite element method which was developed to describe the problem.

The experimental model is a three storey 3D building, having three flat shear walls and one of a "Π" – shape, used for the elevator, at every level. For the finite analysis of the building we use a four node quadrilateral thin flat shell element, which has six degrees of freedom (dof) per node. The sixth dof is obtained by combining by a membrane element with a normal rotation θz, the so-called the drilling degree of freedom, and a discrete Kirchhof plate element. The drilling dof is introduced via the variational formulation. The variational formulation employs enforcement of equality of the independent rotation field and skew-symmetric part of the displacement gradient.

The specimens are made of Lexan. This material is suitable for both photoelastic and caustic optical method techniques. According to the photoelastic method the specimen is placed between the plates of a circularly polarized field, so that isochromatic fringes patterns can be taken. These fringes give the principal stress difference of an existing stress field.

The parameters under investigation are the type of the elements used, the use of diaphragm or not and the size of the mesh. The results obtained for this characteristic test problem indicate that using the specific quadrilateral shell finite element, and having a medium mesh we can perfectly model this building.

References:

[1] Bathe, K.J. "*Finite Element Procedures*", Prentice Hall, Englewood Cliffs, N.J., (1996).
[2] Zienkiewicz, O.C. and Taylor, R.L., "*The Finite Element Method Vol. I: Basic*

Formulations and Linear Problems", McGraw – Hill Book Company, U.K., (1989).
[3] Jin, L. "*Analysis and Evaluation of a Shell Finite Element with Drilling Degree of Freedom*", University of Meryland at College Park, (1996).
[4] Badalouka, B.G., Papadopoulos, G.A. and Badaloukas, G.N. "*An experimental study of pre-stressed beam by means of optical methods*", 3rd National Conference on Computational Mechanics, University of Thessaly, Volos, Greece (1999).

FAILURE OF A COMPOSITE WITH A BROKEN FIBER

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ABSTRACT

It is possible for various reasons, during the fabrication procedure of composite material structural elements the breaking of the continuous fibers used as reinforcement, will be occurred Thus, the end product includes initial defects which influence the mechanical behavior of the structural element. In this paper a mechanical model is introduced for the study of the problem. According to which a cylindrical fiber enclosed by different materials, which play the role of the matrix, is assumed. Uniaxial tensile stress parallel to the axis of the fiber is imposed. Developing stress and strain field are determined using the finite element program ABAQUS. The influence of the geometry parameters and material properties on the developing stress field is thoroughly examined. Emphasis is given in the failure mechanism in the critical area of the model. For the matrix failure the strain energy density criterion is used whereas for the debonding of the fiber the energy release rate is applied.

Keywords: Composite Materials, Fracture, Finite Elements, Strain Energy Density Theory.

MICROMECHANICS OF CARBON FIBRE MODEL COMPOSITES UNDER TENSILE, COMPRESSIVE AND FATIGUE LOADING CONDITIONS

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ABSTRACT

The macroscopic mechanical behaviour of composite materials under externally applied loads is mainly determined from the way the mechanical load is transferred from the matrix to the fibres at a microscopic level. The main load transfer mechanism is shear, which takes place at the fibre-matrix interface at discontinuities such as fibre ends or fibre breaks. In this work the micromechanics behaviour of carbon fibre composites was examined under tensile, compressive and fatigue loading in a model single carbon fibre/ epoxy composite geometry and full composites. In all the cases the fibre stress (strain) distribution along the fibre fragments was derived through Raman spectroscopy. The interfacial shear stress distribution was evaluated by means of a balance of forces argument.

Different trends in compression and tension have been observed. In the elastic regime the stress (strain) profiles were almost identical in both cases. Upon increasing the externally applied strain a deviation from linearity was observed in the case of compression as manifested by the multiple fibre fractures (shear breaks). It is worth noting that fibre failure was not observed in tension, however, a clear interfacial damage near the fibre ends was observed at 0.8%. Thus, the interplay between fibre integrity and interfacial failure appears to be dependent upon mode of loading in these systems. After fibre failure, fibre fragments remained in contact (sliding past each other) and thus stress is transferred through fibre ends.

The influence of fatigue loading on the interface properties has also been examined. Initially, the model composites were subjected to cyclic loading at a maximum strain below the critical fatigue limit of the matrix material. The embedded fibres, though, were fatigued at different strain levels due to their prestrain levels, which has been applied prior to the specimen preparation. The results showed that the main fatigue damage parameter that affected the stress transfer efficiency at the interface was the fibre fracture process itself and not the degradation of the interface due to fatigue loading. Finally, experiments on 4-ply UD composites are in progress and results are going to be presented at the conference.

DYNAMIC BEHAVIOR OF A HANGED CABLE FOR DEEP WATER APPLICATIONS

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ABSTRACT

Marine cable systems are used in a wide variety of offshore operations. These include the deployment and the recovery of instrumentation packages, salvage operations, underwater construction, scientific deep ocean coring studies and deep ocean mining activities. These systems utilize wire rope, chain or synthetic rope, and are sometimes used with in combination with slender pipe sections. The cable portions are configured with either single or multiple lines depending upon the particular application.

The present paper is a contribution to the direction of studying the dynamic behavior of a cable, hanged from a floating offshore structure. The governing equations describing the dynamic equilibrium are given though a set of differential equations of the continuous system in 3D space. The dynamic model is fully described by applying proper boundary conditions at both cable ends. The hanged nose of the cable is the location of excitation, and thus the upper end boundary conditions are univocally defined. The boundary conditions in the opposite edge of the cable account in turn for free end as well as for a specific hanged load. The system of differential equations is being solved in time domain by utilizing the well-known method of separation of variables and by applying an efficient pseudospectral method using Chebyshev polynomials for the spatial description along the cable. The time integration of the converted system is being carried out using an implicit finite differences numerical scheme. The method has been already successfully applied for the prediction of the dynamic behavior of catenary-type mooring lines [1] and it is now extended to the case of hanged cables with a suspended weight at their lower end.

The behavior in time of the dynamic system is being analyzed by elaborating the extensive numerical predictions obtained though the numerical simulation of the response. Special attention has been paid in the area of excitation frequencies around the first natural frequency of the dynamic system. For this purpose, the system's first natural frequency is estimated both through observation of the obtained numerical results as well as through the use the Lagrange equation of motion.

References:

[1] Chatjigeorgiou, I.K., Mavrakos, S.A.: "Non - Linear Contributions in the Prediction of the Dynamic Tension on Mooring Lines, for High and Low Frequencies of Excitation", Proceedings, *7th International Symposium on Offshore and Polar Engineering (ISOPE' 97)*, Honolulu, Hawaii, Vol. II, 192 – 199

[2] Chatjigeorgiou, I.K., Mavrakos, S.A.: "Comparison of Numerical Methods for Predicting the Dynamic Behaviour of Mooring Lines", Proceedings, *9th International Symposium of Offshore and Polar Engineering (ISOPE' 99)*, Brest, France, 1999, Vol. II, 332-339.

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EXPERIMENTS FOR THE ESTIMATION OF UNSATURATED HYDRAULIC CONDUCTIVITY

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ABSTRACT

Hydraulic conductivity is one of the most important physical parameter during water movement in porous media and is determined by direct and indirect experimental methods or using numerical and analytical prediction models.

This paper presents experiments for the determination of unsaturated hydraulic conductivity in porous media using direct method, undertaken in the Laboratory of Agricultural Hydraulic in the Department of Rural and Surveying Engineering in A.U.Th. For the determination of unsaturated hydraulic conductivity a dosimeter pump, a system of tensiometers with pressure transducers and a γ –ray device were used. The dosimeter pump supplied water at the top of an experimental column in small quantities (submultiples of the saturated hydraulic conductivity). The soil water content was measured using γ- ray absorption method and the negative water pressure in the pore media was measured using the system of tensiometers with pressure transducers. This way the determination of experimental values (θ_i, Ψ_i) and (θ_i, K_i) was possible and the curve $K(\Psi)$ could be determined.

6th National Congress on Mechanics

Thursday 20 July

USE OF COHESIVE ZONE MODELS FOR ELASTIC-PLASTIC CRACK GROWTH

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ABSTRACT

Plastic dissipation contributes significantly to the total work of fracture during crack growth in metals and polymeric solids. This dependence can be quantified, by representing the fracture process in terms of a traction-separation law, where the work of separation per unit area and the peak normal stress are characteristic parameters, while the material around the growing crack is elastic-plastic.

In some of the studies to be presented this type of cohesive zone modelling is used to determine resistance curves for crack growth under small scale yielding conditions. The cases studied include crack growth in a homogeneous material, T-stress effects on the toughness, mixed mode crack growth along the interface to a rigid solid, and mixed mode crack growth between dissimilar elastic-plastic solids.

Also the debonding of the fibre-matrix interface in a metal matrix composite is an example of interface crack growth under various mixed mode conditions, but here the crack growth typically takes place under full scale yielding in configurations determined by the fibre geometries and spacings.

When fracture occurs by atomic separation, continuum plasticity does not allow for a realistic representation of the fracture process. Computations of the fracture process based on using an elastic core region are briefly discussed.

CONTINUUM THEORY OF SELF-HEALING INTERFACE CRACKS

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ABSTRACT

This talk will begin by discussing the science of fracture mechanics, and the types of questions it can and cannot answer. Many of the unsolved problems involve a combination of dynamic and atomic-scale effects. After showing how these problems appear in brittle amorphous materials, the focus will shift to the fracture of ideally brittle crystals, an area in which a detailed understanding of fracture is emerging. Fracture of this type has a complete analytical solution in special limits, and is generally amenable to large numerical studies. Theoretical predictions can be tested experimentally in brittle crystals such as silicon. In addition to discussing the latest experimental results in single crystals, the talk will finally discuss an unexpected theoretical connection between the problems of fracture and friction.

POSSIBLE AVERAGE FIELDS IN LINEAR AND NON-LINEAR COMPOSITES

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ABSTRACT

Given a two-phase composite of two isotropic elastic phases mixed in fixed proportion one may ask the question: what are the possible values the average strain can take when the average stress is specified? The example of composite materials with negative Poisson's ratio that expand laterally as they are stretched longitudinally, shows that composites can sometimes exhibit an unexpected response. Also what microgeometries produce an extreme value of the average stress for a given average strain? Such microgeometries should be useful as ``stress guides" for channelling stress to desired locations.

One particularly interesting question is what microstructures make the best possible ``hydrostatic compression to shear" converters? Specifically, given a hydrostatic average stress, what anisotropic microstructures produce average strains having the maximum possible ratio between its largest and smallest eigenvalues? The answer to this question in three dimensions could have an impact on the design of hydrophones for the underwater detection of submarines or schools of fish.

For non-linear conducting composites one may ask the simpler question of what values the average electrical current can take when the average electrical field is fixed? What microstructures produce the maximum or minimum current flow? Which microstructures are best for guiding the current in a given direction? This lecture will address these questions.

MATERIAL DEGRADATION AND FRACTURE IN HYDRIDE FORMING METALS

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ABSTRACT

The degradation of metals, caused by the formation of hydrides, is simulated. The model takes into account the coupling of hydrogen diffusion, hydride precipitation, non-mechanical energy flow and hydride/solid-solution deformation. Crack growth is also simulated by using de-cohesion model with a time-dependent energy of de-cohesion, due to the gradual precipitation of the hydrides.

The hydrogen embrittlement model has been implemented numerically into a finite element framework and tested successfully against experimental data and analytical solutions on hydrogen thermal transport (Varias and Massih, 1999, 2000).

The model has been used for the simulation of Zircaloy-2 hydrogen embrittlement and delayed hydride cracking initiation, under K-field dominance as well as under conditions leading to loss of K-field dominance. The effects of near-tip stress intensification as well as of temperature gradient on hydride precipitation and material damage have been studied. The numerical simulation predicts hydride precipitation at a small distance from the crack tip. When the remote loading is sufficient, the near tip hydrides fracture. Thus a microcrack is generated, which is separated from the main crack by a ductile ligament, in agreement with experimental observations.

References:

[1] Varias, A.G. and Massih, A.R., (2000), 'Simulation of Hydrogen Embrittlement in Zirconium Alloys under Stress and Temperature Gradients', *Journal of Nuclear Materials*, Vol. 279, pp. 273-285.

[2] Varias, A.G. and Massih, A.R., (1999), 'Simulation of Hydride Formation and Fracture in Zirconium Alloys', *Proceedings of the European Conference on Computational Mechanics 1999*, (edited by Wunderlich, W.), Munich, Germany.

PROBLEMS OF ELECTROMECHANICAL FRACTURE OF DIELECTRICS AND PIEZOELECTRICS

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ABSTRACT

The analysis of solid state devices of piezoelectronics shows that mechanical or electrical loading causes stress and electrical field intensification at crack tips as well as at sharp edges of surface or embedded electrodes. Therefore discontinuity surfaces present always in real materials may become unstable under certain conditions and rapidly propagate causing eventual fracture of a body as a whole. Griffith's energy balance method has provided a powerful tool both for the theoretical study of fracture processes and for practical calculations for structural members. It is of interest that as early as 1927, at the dawn of fracture mechanics, Griffith's approach was used first by Gorowits in analysis of fracture of dielectrics subjected to strong electric field. A generalization to piezoelectric media of the energy balance conditions was made only half a century later in papers of Parton (1976) and Kudryavtsev *et al.* (1975a, b). Griffith's energy accounting was applied by Suo *et al.* (1992) to study crack growth for ferroelectric ceramics under small-scale hysteresis.

The general theory of the motion of singularities developed by Cherepanov (1977) for an electromagnetic continuum is based on the invariance of certain Γ-integrals with respect to their integration path around a singular point.

There is a characteristic feature which is common to linear problems of electroelasticity dealing with unbounded crack-containing piezoelectric media. It is that the mechanical stresses, strains, and electric field components go to infinity at the tip of a crack, the order of singularity, $1/2$, being independent of the length of the crack (Parton and Kudryavtsev, 1988). For a crack lying in the interface between two unlike materials, the near-tip electroelastic fields are of a more complex oscillating nature (Kudryavtsev *et al.*, 1975a, b; Suo *et al.*, 1992). The oscillating singularity is rather limited in space, however, Kudryavtsev *et al.* (1975a) estimate its size at about 2.5×10^{-4} of the crack length. In bounded piezoelectric bodies all the microscopic processes in the vicinity of the crack tip must be controlled by the coefficients of singularities (intensity factors) when an annulus exists around the crack in which the field is described by the above-mentioned singular solutions. When the charge density intensity factor K_q is introduced, it proves possible (Senik, 1987; Parton *et al.*, 1988) to define a certain critical value of this quantity, K_q^c, and to write

$$K_q = K_q^c \qquad (1)$$

as the condition for the electrical breakdown of a dielectric medium. An alternative but totally equivalent expression may be written in terms of Γ-integrals. The well-known crack extension criteria are adaptable to the electromechanical fracture of dielectrics and piezoelectrics as was discussed by Parton *et al.* (1991) and by Bardzokas *et al.* (1994).

If there are cracks or inclusions in the piezoelectric medium under study, special attention should be given to the electroelastic conditions associated with these imperfections. Parton (1976) and Polovinkina and Ulitko (1978) took the conditions of ideal contact between two sides of a crack

$$D_n^+ = D_n^-\,, \quad \varphi^+ = \varphi^- \qquad (2)$$

D_n being the normal component of the induction and φ the electric potential. Deeg (1980), Pak (1990), Sosa (1992) and Suo et al. (1992) adopted another set of boundary conditions on a perfectly insulating crack

$$D_n^+ = D_n^- = 0 \qquad (3)$$

In air-filled cracks, however, this condition should not be fulfilled due to possible ionization and breakdown of air gap as stated by Balygin (1974) and Koikov and Izykin (1968). McMeeking (1987) modeled cracks containing a conducting fluid with the use of following boundary conditions

$$\varphi^+ = \varphi^- \qquad (4)$$

Senik (1987) investigated general electrical boundary conditions to be satisfied in the case of a long dielectric inclusion. The special cases considered in the study are the ideal contact conditions, a perfectly insulating inclusion, and inclusions with a high or low permittivity (2-4).

Methods of fracture mechanics are applied in analysis of electrical breakdown of by dielectrics and electromechanical fracture of piezoelectrics. The Griffith's energy balance method as well as the intensity factor approach and invariant integral theory are used when formulating criteria of electrical breakdown and electromechanical fracture. The controlling factors for these phenomena proved to be the stress intensity factors and the charge density intensity factor at the crack tip or at the edge of electrode. Several problems of electrical breakdown of dielectrics are considered and the results are correlated with experimental data. The piezoelectric theory of Mindlin is used in analysis of the effect of non-uniform electric field on the crack instability. The obtained solution of antiplane crack problem shows that the stress state of dielectrics and its strength is appreciably affected by the non uniform electric field.

Keywords: Breakdown, electromechanical fracture, dielectrics, piezoelectrics, crack, electrode, fracture criteria.

References:

[1] Balygin, I.E. (1974). *Electrical Properties of Dielectric Solids.* Energiya, Leningrad.

[2] Bardzokas, D., B.A. Kudryavtsev and N.A. Senik (1994) On criteria for electromechanical fracture of piezoelectrics initiated by edges of electrodes. *Intern. J. Strength of Mater.*, 42-46.

[3] Bateman, H. and A. Erdelyi (1954). *Tables of Integral Transformations.* McGraw-Hill, New York *et al.*

[4] Cherepanov, G.P. (1977). Invariant Γ-integrals and their application in mechanics. *Prikl. Mat. i Mekh.*, **41**, 399-412.

[5] Deeg, W.F. (1980). The analysis of dislocation, crack and inclusion problems in piezoelectric solids. Ph.D. Thesis, Stanford University, CA.

[6] Oikov, S.N. and A.N. Izykin (1968). *Electrical Aging of Dielectric Solids.* Energiya, Leningrad.

[7] Kudryavtsev, B.A., V.Z. Parton and V.I. Rakitin (1975a). Fracture mechanics of piezoelectric materials. Rectilinear tunnel crack in the conductor-piezoelectric interface. *Prikl. Mat. i Mech.*, **39**, 149-159.

[8] Kudryavtsev, B.A., V.Z. Parton and V.I. Rakitin (1975b). Fracture mechanics of piezoelectric materials. An axisymmetric crack in the interface with a conductor. *Prikl. Mat. i Mech.*, **39**, 352-362.

[9] McMeeking, R.M. (1987). On mechanical stresses at cracks in dielectrics with application to dielectric breakdown. *J. Appl. Phys.*, **62**, 3116-3122.

[10] Pak, Y.E. (1990). Crack extension force in a piezoelectric material. *J. Appl. Mech.*, **57**, 641-653.

[11] Parton, V.Z. (1976). Fracture mechanics of piezoelectric materials. *Acta Astro.*, **3**, 671-683.

[12] Parton, V.Z. and B.A. Kudryavtsev (1988). *Electromagnetoelasticity.* Gordon and Breach, New York.

[13] Polovinkina, I.B. and A.F. Ulitko (1978). On the equilibrium of piezoceramic bodies containing cracks. In: *Thermal Stresses in Structural Members.* Pp. 10-17, Naukova Dumka, Kiev.

[14] Senik, N.A. (1987). Application of fracture mechanics to dielectric breakdown problems. In: Proc. 1st USSR Nat. Conf. Fracture Mechanics, Lvov. Oct. 20-21, 1986, p. 298.

[15] Sosa, H. (1992). On the fracture mechanics of piezoelectric solids. *Intern. J. Solids and Struct.*, **29**, 2613-2622.

[16] Suo, Z., C.-M. Kuo, D.M. Barnett and J.R. Willis (1992). Fracture mechanics for piezoelectric ceramics. *J. Mech. and Phys. Solids*, **40**, 739-765.

CONTROL OF DYNAMIC STRESS AND FRACTURE OF PIEZOELECTRIC BODIES WITH CRACKS

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ABSTRACT

Rapid development of production technologies and also significant progress of the investigation of the fracture mechanics stimulates consideration of new problems of fracture control of piezoceramic bodies. Fracture control is necessary in different fields of industry, e.g. during cutting of metals, cracking of marble plates, drilling of borcholes, mining of deposits, etc.

In a piezoelectric body the interaction of elastic waves with failures like cracks in their vicinities there appear singular conjugate mechanical and electrical fields which may bring to mechanical and electrical fracture of the body. The analysis of probability of the fracture is based on the results of solving of the dynamic boundary problem of electroelasticity. The speed of energy release in the process of the crack propagation is expressed by the stress intensity factor (SIF), which are the functionals determined from solutions of integral equations of the electroelasticity boundary problem.

The approach to the solution of the problem of optimal control of parameters, regulating the fracture of a piezoelectric body with cracks and a piezoelectric bimorph with an interphase crack is proposed here as well.

OPTIMIZATION AND SOFT COMPUTING FOR INVERSE AND CRACK IDENTIFICATION

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ABSTRACT

Inverse problems in engineering are formulated as output error minimization problems. Inverse crack and flaw identification problems are investigated, with an emphasis on partially or totally closed (unilateral) cracks. The computer implementation uses appropriate, parametrized boundary element techniques in statics and dynamics. The inverse problem is solved by several numerical optimization and soft computing tools, which include neural networks and genetic algorithm schemes. Results from our current investigation in this area will be reported. Previous recent results of our group have been summarized in the monography [1].

References:

[1] G.E. Stavroulakis, Inverse and crack identification problems in engineering mechanics. Habilitation Thesis, Technical University of Braunschweig, Germany and Kluwer Academic Publishers, Boston, Dordrecht, London, 2000.

MECHANICAL BEHAVIOR OF MULTILAYERED NANOCOMPOSITE FILMS

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ABSTRACT

Nanoscale composites consisting of alternating layers of metallic and ceramic phases may offer novel mechanical properties and considerable potential as high strength, high toughness and high wear resistance surface coating materials. It has been shown, that in nanolayered composites, the interlamellar spacing mainly controls the mechanical properties and Koehler strengthening effects can be realized below a critical layer thickness that relates to the inability of Frank-Read dislocation sources to operate. In the present work, the mechanical and tribological properties of three nanolayered composite model systems were investigated. Nanolaminate composites of Al/Al_2O_3, Ti/TiN, and Cr/DLC (diamondlike carbon) were synthesized using a hybrid chemical vapor deposition/physical vapor deposition system that combines intensified plasma and sputter deposition. Composite multilayers were developed with interlamellar spacing below and above the critical thickness. High-resolution transmission electron microscopy was used to analyze the structure, metal/ceramic interface and characteristics of the multilayers. Nanoindentation experiments were conducted at various loads to determine force-displacement curves, which were used to calculate elastic moduli and nanohardness as a function of interlamellar spacing. Friction and wear behavior of nanolaminates was studied by conducting pin-on-disc experiments. It was observed that the layer thickness of the multiplayer composites has a systematic effect in the mechanical properties. The processing-structure-mechanical property relationship is discussed in view of the experimental evidence.

A COMPARATIVE STUDY OF MECHANICAL PROPERTIES OF STATE-OF-THE-ART CARBON BASED FILMS

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ABSTRACT

Carbon based films is a group of very similar but still very different materials. Depending on the deposition technique, their properties range from graphite-like to diamond-like. Due to their outstanding and tunable properties (hardness, wear resistance, coefficient of friction, transparency, chemical inertness, relatively low electron affinity and biocompatibility), carbon based films exhibit an increasing number of applications in nanoscale components such as those used in magnetic hard discs, wear-resistant coatings, outer layer for medical implants and they are promising in semiconductor devices, optical film applications and in large area electron field emitting devices.

In this study the mechanical and tribological properties of various state-of-the-art carbon based films, namely very thin (sp^2, sp^3 rich) sputtered amorphous carbon (a-C) films, thin, hard and rich in sp^3 sites layered-structure sputtered a-C films, nitrogenated a-CN_x sputtered films and tetrahedral a-C films grown with vacuum arc technique are compared. Aspects that are important in assessing the potential use of carbon based films are not only the elastic properties (hardness (H) and elastic modulus (E)) of the film, but also the adhesion of films onto the substrate, and their deformation response (elastic/plastic) under contact events. Another primary material property, which is related to the ratio of H and E and defines the wear resistance of the films, is also studied.

The techniques of nanoindentation and nanoscratching with the high load (displacement) resolution in the mN- and nm- range and the continuous depth-sensing indentation tests provide the capabilities to assess the detailed mechanical responses of the film-substrate system, especially at contact scales of the order of, or less than, the film thickness. The results of this work demonstrate that the mechanical and tribological properties of carbon based films strongly vary. Each film type has specific advantages and the complete range of properties should be considered to select the appropriate film in a particular application.

THE ROLE OF POINT DEFECTS ON THE GROWTH AND BREAKDOWN OF METAL PASSIVE FILMS IN ELECTROLYTE SOLUTIONS

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ABSTRACT

A passive metal in an aqueous electrolyte is covered by a barrier film, which is usually modeled as an oxide ($MO_{x/2}$) with semiconductive properties. The oxide contains a high concentration of point defects (anion and cation vacancies) that determine the oxide growth and breakdown processes. Oxide growth takes place electrochemically at applied potentials positive to a passivation potential, called as Flade potential (E_F). The transport of metal ions, oxygen ions and cation, anion vacancies takes place across the oxide and the metal|oxide, oxide|electrolyte interfaces. Certain halide ions X^- (X^- : Cl^-, Br^-, I^-) lead to a local breakdown of the oxide film (pitting corrosion) whereas the F^- ions lead to a uniform dissolution of the oxide film (general corrosion). The objective of the present study is to distinguish between pitting and general corrosion based on the non-linear dynamical response of the $Fe|FeO_{x/2}|H_2SO_4$ system perturbed chemically by X^-.

In the characteristic current-potential curve of iron in sulfuric acid solutions there is a potential region, located close to the E_F and the passive-active transition, which shows bistability and oscillatory behavior. The non-linear response of the system consists of monoperiodic current oscillations of a relaxation type. The maximum and the minimum of the oscillating current correspond to the active and passive state of the metal, respectively.

The presence of a low concentration of halides results in a perturbation of the passive-active transition, which leads to complex periodic and aperiodic (chaotic) oscillations. Both the oscillatory and passive regions are determined by the physicochemical processes occurring at the $FeO_{x/2}$ and $Fe|FeO_{x/2}$, $FeO_{x/2}|H_2SO_4$, X^- interfaces. A point defect model is used for the description of the semiconductive film in order to explain the difference between pitting and general corrosion. This model takes into account the fluxes of anion and cation vacancies as well as the electrochemical and chemical reactions through the oxide and metal|oxide, oxide|electrolyte interfaces. The pitting corrosion arises from the attack of Cl^-, Br^-, I^- at an anion vacancy whereas the general corrosion arises from the attack of F^- at a lattice oxide site. This finding is in agreement with our experimental observations.

References:

[1] D. Sazou, A. Karantonis, M. Pagitsas, I. J. Bif. & Chaos 3 (1993) 981.
[2] M. Pagitsas, D. Sazou, J. Electroanal. Chem. 471 (1999) 132.
[3] D. Sazou, A. Diamantopoulou, M. Pagitsas, Electrochim. Acta 45 (2000) 2753.

FAILURE RESISTANCE TO THERMAL SHOCK OF THERMAL BARRIER COATINGS USING THE FINITE ELEMENT METHOD

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ABSTRACT

The failure resistance to thermal shock of a thermal barrier coating containing an interfacial crack is investigated via the finite element method. Linear elastic fracture mechanics analysis is used to determine the effects of various material property combinations and coating thickness, temperature-dependence of material properties, heating versus cooling and thermal cycling. The modulus of the transient complex thermal stress intensity factor $\boldsymbol{K}^*$, introduced by Rice, is obtained using the crack flank displacement method of Smelser. It is demonstrated that a cooled center crack is more susceptible to propagation than when heated, whereas for an edge crack the stress intensity factor peaks at steady-state. In the case of thermal cycling the largest $\boldsymbol{K}^*$ occurs in transient for all crack configurations. Resulting transient $\boldsymbol{K}^*$ also illustrates that increasing adhesive thickness increases the resistance to fracture. In respect of thermal and mechanical material property combinations, it is understood that an optimisation process or in other word a functionally gradient material, would result in a decrease in the load that the cracks experience and therefore, would lead to an improved failure resistance.

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FINITE ELEMENT ANALYSIS OF THE ELASTIC MECHANICAL BEHAVIOUR OF LDPE FILM

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ABSTRACT

During the last years the use of plastic films in agriculture has increased dramatically due to their good mechanical properties, ease of forming and low cost. In particular, Low-Density Polyethylene (LDPE) films, representing the vast majority of the plastic covering materials of greenhouses with a predictable life-time, has contributed to increasing the quality and quantity of the crop production and to reducing some problems related to the greenhouse design. All service conditions for the LDPE greenhouse films involve mechanical stress under various loading conditions while the durability of these materials mainly depends on their mechanical behaviour. Therefore, the investigation of the mechanical behaviour of the LDPE films is a significant issue.

In the present work, the elastic mechanical behaviour of LDPE films under various combinations of pre-tensioning and uniform pressure schemes is investigated both experimentally and numerically. The results of the experimental set-up, involving monitoring the mechanical behaviour of a pre-tensioned and uniformly loaded square piece of film, are compared against the results obtained from analytical expressions reported in the literature [1, 2] and the results obtained using the finite element method of analysis.

The large deformations finite element nonlinear analysis is performed by using a commercial program (ANSYS) [3] as well as a research program employing the finite shell element RFNS [4]. The material elastic model developed is based on the corresponding behaviour and the mechanical properties obtained at the laboratory by applying standard testing methods [5].
An excellent agreement between experimental, analytical (whenever available) and numerical results is achieved. This study will be used subsequently for the analysis of the state of stress of greenhouse LDPE films, under various loading conditions.

References:

[1] Leonard, J. W. (1988). "*Tension Structures. Behavior and analysis.*" McGraw- Hill.

[2] Timoshenko, S. and Woinowsky-Krieger, S. (1959). "*Theory of plates and shells.*" McGraw- Hill.

[3] ANSYS (1999). v. 5.5, ANSYS Inc., Canonsburg, USA

[4] Briassoulis D.(1996)."The Four-node C° Shell Element Reformulated', *Int. J. Numer. Meth. Eng.*,39, 2417-2455.

ADAPTIVE COMPOSITES INCORPORATING SHAPE MEMORY ALLOY WIRES; RECORDING THE INTERNAL STRESS BY LASER RAMAN SPECTROSCOPY

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ABSTRACT

Pre-strained Shape Memory Alloy (SMA) wires have been integrated in composite laminates consisting of an epoxy resin reinforced by aramid fibres. The SMA wires, in tandem with their reinforcing role, can act as sensors and/or actuators changing the structural behaviour of the composite materials due to their ability to generate recovery stress.

Laser Raman spectroscopy is considered as a powerful method for stress or strain measurements in fibrous composite materials. Past work has shown that Raman vibrational wavenumbers of the skeletal backbone shift to lower values under tension and/or temperature and to higher values under compression and well-defined relationships between Raman wavenumber and applied stress, strain or temperature can be obtained for the aramid fibres. Using a non-skeletal vibration which is insensitive in temperature along with a previously developed methodology, the transmitted stresses from the wires to fibres can be quantified.

In this work we report on the transmitted stresses from wires to fibres as a function of activation temperature in SMA wires/ aramid fibre/epoxy composites. The SMA wires were prestrained by 3% and were resistively activated generating internal compressive stresses at different activation levels (temperatures). The dimensions of the used specimen were carefully selected in order to avoid geometrical failure.

Transmitted compressive stresses were measured at temperatures of 60, 80 and 100 °C for an SMA composite specimen by employing different SMA wire volume fractions. The results show that the stress values of 100 °C activation are not significantly different than those at 80 °C in all cases, while the transmitted stresses are dependent on the interwire distance. An attempt to relate the transmitted stresses to the SMA wire volume fraction and thus to the normalised interwire distance, r/R, where r is the position of the fibre normal to the wire direction and R is the wire radius, will be presented at the conference.

A HEMIVARIATIONAL INEQUALITY APPROACH TO THE RESISTANCE OF ALUMINIUM RIVETED CONNECTIONS

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ABSTRACT

A hemivariational inequality approach is herein proposed to study the bearing resistance of aluminum riveted joints. Taking into account nonlinear effects such as plasticity and interface interaction and describing the resistance in bearing strength by means of a nonmonotone multivalued reaction-displacement law taken from experimental testing, the problem is formulated as a hemivariational inequality one. The latter is equivalent to a substationarity problem of the potential energy of the aluminium joint at hand. This problem can be effectively treated numerically by applying an appropriately chosen nonsmooth nonconvex, optimization algorithm. In the last part of the paper, the results of a numerical application are compared to those of an experimental testing program that has been performed in the laboratory to investigate the resistance of aluminium riveted joints.

Keywords: Hemivariational Inequalities, Nonsmooth Optimization, Aluminium Connections.

ANALYSIS OF "CONVEX ENERGY" STRUCTURAL SYSTEMS UNDER STOCHASTIC LOADING

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ABSTRACT

The stochastic behaviour of unilateral structural elements (or components) is a field that has only sporadically investigated due to the high complexity of both the stochastic nature of the actions and the highly non-linear unilateral behaviour of the respective structural system (e.g. bolted metallic connections with elasto-plastic material behaviour, cable structures, etc.). In particular, the unilateral contact problems of monotone nature can be formulated within a Non-smooth Mechanics framework as constrained minimization problems of the potential energy of the structures, and are numerically treated by means of efficient convex optimisation algorithms (for instance, the Hildreth - d'Esopo or the Theil - van de Panne algorithm). As a matter of fact, for this class of problems, the response has to be treated with utmost care because explicit and conditionally stable integration algorithms cannot be employed. This highly non-linear behaviour has to be taken into account and coupled with the stochastic nature of the actions in the analysis procedures in order to achieve the respective process of the stochastic structural response (displacement and strain field). It is important to point out that conventional methods applied to the investigation of such problems may lead to erroneous results. For this reason appropriately modified F.E. models have to be employed for a more realistic description of the effect of the stochastic actions joined with the unilateral contact elements. The aim of the present paper is to integrate in a unified effective framework the two main aspects introduced above. In addition, this paper tries to offer a suitable method for modelling the structural response of these mechanical systems for a more realistic and adherent description of the actual response. The herein proposed stochastic approach to unilateral contact problems (that introduces a more realistic description of the effective nature of the loads) leads to significant improvement of the actual behaviour of the real structures and the design criteria for the respective structural elements.

Key words: stochastic behaviour, unilateral contact problems, convex energy system

FRICTION EVOLUTION IN FRACTAL INTERFACES

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ABSTRACT

Surface topography plays an important role in contact problems. It is well known that the topography of engineered surfaces and interfaces is too complex to be described by few parameters. It has been shown that the roughness of these surfaces has multiscale nature and needs new advanced mathematical techniques for its description.

Fractal geometry provides both a general description and a mathematical model for complex forms found in nature. This fact makes fractal geometry central to various fields of science such as physics, biology, geology and material science. In applied mechanics the property of fractality appears very often. For instance the cracks and interfaces in rocks, in composite materials, in concrete and masonry structures are of fractal type. Experimental data verify the fractality of rough surfaces and interfaces Saouma et al. (1990), Mandelbrot et al. (1984), Xie (1989) and Xie (1991).

Mandelbrot first introduced the term ``fractal" in Mandelbrot (1982). According to his definition a set $A \subset R^n$ is a fractal if $A$ has fractional ``Hausdorff" dimension, or if the dimension of A is an integer strictly larger than its topological dimension. The mathematical concept of the Hausdorff dimension, which presupposes a scaling down procedure for any physical object up to infinitely small scales, is applicable to mathematical models rather than to physical objects. Moreover, the Hausdorff dimension cannot be obtained by experimental procedures. On the other hand, it must be mentioned here that there is no canonical definition of physical fractals, but there are numerous methods for the practical estimation of the fractal dimension of an object.

For these reasons the mathematical approaches to the theory of fractals followed here Barnsley (1988), Massopust (1993), Borodich and Onishchenko (1999) are based on an iterative procedure which seems to be appropriate for the problems in mechanics. All these approaches use classical geometrical manipulations (for example affine transformations, scaling and rotations) to express relations between parts of fractal sets.

The main purpose of this paper is to investigate the influence of the fractality of an interface on the development of the friction mechanism. For that, it is assumed that different interfaces, described by fractal geometry, are developed in a certain structure in which the material is assumed to have an elastic-plastic behaviour. For every structure, resulting from each fractal interface, the same boundary conditions and loading are assumed. In the method proposed here the fractal interfaces are approximated by a sequence of classical curves. Each one of the

corresponding problems, involving classical geometry, is solved and at the limit the solution of the initial fractal problem is given. In the sequence, the results corresponding to different interfaces are studied with respect to the way that the friction mechanism is developed. Finally, it is examined how the friction mechanism is affected by the different fractal dimensions and usefull conclusions are derived.

NUMERICAL STUDY OF THE F.E. MESH DEPENDENCY IN NONCONVEX-NONSMOOTH ENGINEERING PROBLEMS

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ABSTRACT

There are many problems in Mechanics where constitutive or boundary laws are represented by relations involving decreasing branches (for example reaction-displacement laws in interface problems, general nonmonotone friction laws, adhesive contact laws in laminated composite problems). Inclusions with nonmonotone relations were introduced in Mechanics by P.D. Panagiotopoulos [1], [2] who termed them hemivariational inequalities. They represent an appropriate tool enabling the study of nonmonotonicity into the mathematical model reflecting the mechanical response. The mathematical analysis of hemivariational inequalities uses methods of nonsmooth and nonconvex analysis [3], [4]. Concerning the numerical treatment, an appropriate discretization is necessary. Then, the continuum problem is replaced by its finite dimensional one. With a model having a finite number of degrees of freedom, there exist a number of methods for the numerical treatment of the problem.

In this paper the heuristic nonconvex optimization approach of [5] is followed according to which the hemivariational inequality is replaced with a sequence of variational inequality problems. The numerical solution of the discretized version of the variational inequalities is then obtained by quadratic programming algorithms.

This approach is applied in order to investigate the dependency of the initial problem on the F.E. discretization used. For this reason several model problems are examined with various F.E. discretization densities. The examples treated here include frictional contact and adhesive contact problems with a strongly nonlinear nature. The dominant role of the possible vertical branches of the reaction-displacement diagrams is studied. Interesting results are obtained with respect to the accuracy expected in such kind of problems.

References:

[1] P. D. Panagiotopoulos, Inequality problems in mechanics and applications. Convex and nonconvex energy functions}, Birkhauser, Basel - Boston - Stuttgart (1985). Russian translation, MIR Publ., Moscow (1988).

[2] P. D. Panagiotopoulos, Hemivariational inequalities. Applications in mechanics and engineering, Springer, Berlin - Heidelberg - New York (1993).

[3] Rockafellar, R. T.: 1979, La theorie des sous-gradients et ses applications a l' optimization. Fonctions convexes et non-convexes, Montreal: Les Presses de l' Universite de Montreal.

[4] Clarke, F. H.: 1983, Optimization and nonsmooth analysis. New York: J. Wiley.

[5] E. S. Mistakidis and G. E. Stavroulakis, Nonconvex optimization in Mechanics. Algorithms, heuristics and engineering application by the F.E.M., Kluwer, Boston (1997).

FUZZY SETS IN ENGINEERING ANALYSIS AND DESIGN

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ABSTRACT

Design in engineering practice is a procedure where the structural engineer attempts to create a structure that will withstand all the loads it is expected to encounted during its intended life. Is has been realized though that the actual strength of the structure cannot be precisely known due various uncertainties. In the following summarize the most important uncertainties in structural analysis problems.

- The actual system is far more complex than the idealized model considered by the design engineer.
- The actual material properties are not exactly known. Usually minimum values are specified by the design engineer that it is more likely to be surpassed in several members. Moreover, the majority of the structures are statically indeterminated a fact that has as a result the dependance of the stresses on the relative stiffnesses of the various interconnected members. As a consequence variances in the material properties results in differences in the values of the developed stresses.
- Enviromental loads, such as snow or wind, have unpredicted future magnitudes. Moreover, seismic loading, the main action in earthquake zones, has an inherent uncertain character. Only maximum values over a range of years are specified by the seismic codes, which are reviewed frequently, giving usually larger values than the previous ones.

It is thus a basic fact of life that the structural resistance and structural loading can only be assessed with a degree of uncertainty. But, classical mathematics is not equiped to deal with uncertain or imprecise descriptions. Traditionally, the design engineers take into account these uncertainties in the design by using the so called "safety factors", i.e. reducing the design strength and increasing the applied loading.

Active research effort took place during the previous years in order to rationalise the design process by introducing design criteria which directly or indirectly employ statistical and probabilistic tools into structural design codes [1], [2], [3]. These methods had the inherent difficulty that required a lot of statistical data for their application that were usually not available. In the sequel probabilitic methods evolved [4] which employed fisrt-order probabilistic theory which used only the mean values and the standard deviation of the random variables. Moreover, special consideration has been given during the past years for the evolution of methods of estimating the reliability of the whole structural system.

In this paper a new approach to the problem of estimating the structural response of systems with uncertain characteristics is presented. The approach is based on the theory of fuzzy sets [5],[6],[7],[8] which allow the designers to describe the uncertain variables. The method is presented briefly in the following. First the uncertain parameters are expressed as fuzzy numbers with certain characteristics. The concurrent effect of the various uncertainties on the structural respose is obtained by applying certain methodologies of the theory of fuzzy sets. Then the output parameters of the design process as e.g. the displacements or the stresses of the structure are obtained as new fuzzy numbers expressing the uncertainties of the output parameters. Finally, numerical applications on a number of relatively simple structural systems give an idea of the applicability of the proposed methodology in various aspects of the design process.

References:

[1] Mayer, M.: Safety of Structures, Springer, Berlin, 1926.

[2] Freudenthal, A.M.: The safety of structures, Transactions of ASCE, 112, 1947, pp.125-180.

[3] Pugsley, A.G.: Concepts of Safety in Structural Engineering, 1951

[4] Benjamin, J.R.: Statistics of Civil Engineers, McGraw-Hill, New York, 1964.

[5] Wood K. L. and E.K. Antonsson: Computations with imprecise parameters in engineering design:Background and theory, ASME J. of Mechanisms, Transmissions and Automation in Design 111(4), 1989, pp. 616-625.

[6] Otto K. N. and E. K. Antonsson: Extensions to the Taguchi method of product design, ASME J. of Mechanical Design 115(1), 1993, pp. 5-13.

[7] Otto K. N. and E. K. Antonsson: Tuning parameters in engineering design, ASME J. of Mechanical Design 115(1), 1993, pp. 14-19.

[8] Zimmermann H. J.: Fuzzy Set Theory and Its Applications, Kluwer, Boston, 1985.

CONTACT MECHANICS OF GEOMECHANICAL INTERFACES SEPARATED BY A WEAK MATERIAL

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ABSTRACT

The presence of a surface coating or in the extreme, a thick layer between faces can strongly influence the behaviour of geomechanical interfaces. The purpose of the paper is to analyse the shear behaviour of such interfaces by means of the basic principles of contact theory. In the analysis all the roughness is assumed to occur on a rigid isotropic surface in contact with a perfectly smooth deforming substrate coated with a deforming layer. In such a system it is apparent that asperities will always be in contact with the weak layer and in some instances may penetrate the layer to contact the substrate. Transverse motion will be resisted by the shear strength of the material which is in contact with each individual asperity. The applied normal load will be carried out by the sum of the load capacity of each asperity contact. This load capacity is the effective hardness of each contact which is different from the harness of either the layer or substrate material.

These physical arguments may be expressed as follows:

$$\mu = \frac{\tau_1 A_1 + \tau_2 A_2}{H_1 A_1 + H_e A_2}$$

where μ is the coefficient of friction , A is the real area of contact, τ is the shear strength and H is the hardness. The suffixes 1 and 2 refer to the substrate and the layer respectively while the suffix e identifies the effective hardness of a substrate covered by a weak layer.

The analysis of contact mechanics is made on the following assumptions:
a) The asperities, at least at their summits, are spherical.
b) All asperity summits have the same radius β
c) The summits are sufficiently apart to deform independently
d) The contacting asperities are clean and unweathered with a composite elastic modulus $E' = [E/2(1-v^2)]$

Based on the Hertzian contact theory between individual asperities, the friction coefficient of the system is found to be equal to

$$\mu = \frac{\mu_{max} \overline{H} \lambda + k \mu_{min}}{\overline{H} \lambda + [1 + (\overline{H} - 1) exp(-\frac{ct}{\beta})] \kappa}$$

where $k=\exp(t/\sigma)-1-t/\sigma$ and μ_{max} is the coefficient of friction surface on surface, μ_{min} is the coefficient of friction surface on layer, t is the thickness of the weak layer, c is the interfacial cohesion and H the composite hardness and σ the standard deviation (rms) value of the asperity distribution. Making some simplifications a simpler expression is derived. This expression is successfully tested against published data.

The main conclusion is that the theoretical analysis followed in the paper can be used in practical applications in the field of rock engineering.

BENDING AND WARPING IN FIBER REINFORCED RECTANGULAR BEAMS

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ABSTRACT

A closed-form solution is proposed for the study of the stresses developed inside fiber reinforced composite beams, which are subjected to simultaneously existing torsion and bending moments. Without loss of generality, the model studied is a clamped-free beam with rectangular section. The beam consists of parallel dispersed hard fibers of Boron inside a soft Epoxy matrix, which form various angles with the longitudinal axis of the beam. The elastic properties of the composite material and the torsional rigidity as well as the stresses of the beam are determined using Sokolnikoff's approach in conjunction with the theory of anisotropic elasticity. The conclusions of our analysis can be summarized as follows:

a) The moduli of the composite expressing the elastic coupling between normal stresses and shear strains are influenced more than the respective shear or elastic moduli by the fiber orientation in the beam.

b) The torsional rigidity of fiber reinforced beams varies strongly with the aspect ratio of sections.

c) The normal stresses attain higher absolutely values in beams subjected to pronounced torsion relatively to the bending applied.

d) The maximum shear stress in fiber reinforced beams appears at various points of the section depending on its aspect ratio as well as the anisotropy of the material.

THE COSSERAT SPECTRUM THEORY AND APPLICATIONS IN SOLID AND FLUID MECHANICS

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ABSTRACT

The homogeneous Navier equations $\nabla^2 u + \omega \vec{\nabla}(\vec{\nabla} \cdot \vec{u}) = 0$, $\left(\omega = \frac{\lambda + \mu}{\mu} = \frac{1}{1-2\nu}\right)$, with homogeneous boundary conditions of place or traction admit non-trivial solutions when ω takes values in a set of points (lying of course outside the physical range for Poisson's ratio) called the Cosserat Spectrum. The properties of the Spectrum and the corresponding eigenfunctions were studied by S.G. Mikhlin who proved completeness, and orthogonality, to be reviewed here briefly. By using these properties we investigate how solutions of the equations of elasticity depend on Poisson's ratio. Furthermore we show that any eigenfunction $\vec{u}$ of the above eigenvalue problem may be visualized as displacement in an equilibrium thermoelastic problem with temperature distributions $T \sim div\, \vec{u}$. Using that the collection of the divergences of the eigenfunctions is complete in L^2 we are able to expand the solutions of the equilibrium equations of thermoelasticity under arbitrary temperature distribution in a rapidly convergent series of the eigenfunctions. We prove that the eigenfunctions can be characterized as stationary points of the Helmholtz free energy (and elastic energy) under the constraint that the thermal part of the free energy $\int T^2 dV$ is constant.

An important application of the Cosserat Spectrum Theory is in Viscoelasticity. The solution for the Laplace transform of the displacement of viscoelastic problems is expressed in series of the Cosserat eigenfunctions, which are dependent only on position and have coefficients that are expressed as convolutions of the time dependent body force or surface loadings (provided that the inverse Laplace transform of the moduli is obtained). This renders the Cosserat Spectrum Theory advantageous for the solution of viscoelastic problems. Applications to fluid and mechanics are also presented both for incompressible and compressible fluids.

ON THE POTENTIAL REPRESENTATIONS FOR POLYADICS AND ANISOTROPIC MEDIA

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ABSTRACT

Helmholtz, in his celebrated paper on vortex motion published in 1858, introduced his famous representation that allows decomposing any smooth vector field in terms of an irrotational and a solenoidal field. If fact, the irrotational part is expressed in terms of a scalar potential and the solenoidal part is expressed in terms of a solenoidal vector potential. The implications of this decomposition to Theoretical Physics and in particular to Mechanics are immense. In order to appreciate just one component of the contribution of Helmholtz's decomposition theorem to Mechanics it is enough to consider studding elastic wave propagation without reference to the decomposition of the displacement field into longitudinal and transverse waves.

In the present work, two principal generalizations of the Helmholtz theorem are reported. The first one concerns potential decomposition of polyadics (tensor products) of any rank and the second one refers to potential decomposition of vector fields that describe anisotropic media. In the first place it is shown that a polyadic of the n-th rank can be expanded into n+1 terms each one of which involves a potential that is a polyadic of some rank between the zeroth and the n-th. As we move from terms involving potentials of higher rank to terms involving potentials of lower rank the tensorial character of the terms is taken up by iterative applications of the gradient operator. The special case of a first rank tensor recovers the Helmholtz decomposition theorem. The importance of this generalization as it is applied mainly to dyadic fields is obvious. As far as anisotropic media are concerned it is shown that the anisotropic response of the medium can be incorporated into a dilation and a rotation of the gradient operator via contraction with a positive definite symmetric dyadic. Then, a sequence of identities relating the above type of deformed gradients leads to a potential representation of any vector field that lives within an anisotropic environment. The implication of this type of generalization to Continuum Mechanics is under current investigation, where an elegant way to deal with anisotropy is observed.

THE APPLICATION OF NOETHER'S THEOREM TO NON-LINEAR ANISOTROPIC ELASTIC MATERIALS

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ABSTRACT

Since the paper of Knowles and Sternberg (1972), a huge number of papers where published in connection with application of Noether's theorem to the problem of conservations laws, and particularly to the path-independent integrals. Almost all of them were dealing with isotropic materials. Very recently, new method has been applied to this problem. This method is known under the name Stroh formalism, and has been used very successfully for different problems for linear anisotropic materials. Therefore, this method is limited to the linear anisotropic materials. But non-linear constitutive relations of materials play an increasing important and key role in contemporary theoretical and applied mechanics.

The problem how to represent anisotropic tensor functions, i.e. how to deal with constitutive equations of anisotropic materials, was pushed a head by the papers of Bochler (1978, 1979). In these works the elegant concept of anisotropic tensors (Smith and Rivlin, 1957a) or structural tensors (Lokhin and Sedov, 1963; Sedov and Lokhin 1963, Boehler, 1978, 1979) which characterize the anisotropy was extended to join the so called principle of isotropy of space that an anisotropic tensor function is expressible as an isotropic one with the structural tensors as the additional tensor agencies (see also Liu, 1982). Thus, the known isotropic tensor function representations can be used to immediately yield representations for anisotropic tensor functions (see, for example, Boehler and Raclin, 1977; Boehler 1977; Liu 1982; Spencer 1982; Boehler, 1987b). Along this line, constitutive laws of transversely isotropic, orthotropic and clinotropic materials for complex irreversible mechanical phenomena such as yielding, failure, creep and damage are well formulated, as described for instance in the articles by Boehler (1982; 1985a; 1987a; 1990; 1993) and Betten (1990; 1991).

Making use of this concept we are able to derive conservation laws for some classes (for all, Xsiao, 1995) of non-linear anisotropic materials in the same way as we do for isotropic materials. More precisely, we may approach the problem of conservation laws for anisotropic materials using Noether's theorem as we do for isotropic non-linear materials. It is the aim of the note.

MICROMECHANICAL MODELING OF THE BEHAVIOR OF POROUS SHAPE MEMORY ALLOYS

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ABSTRACT

In a previous work two methods for modeling porous Shape Memory Alloys (SMAs) - one based on the unit cell FEM and the second using the incremental Mori-Tanaka averaging method - have been presented. The current approach extends the micromechanics averaging method to establish a macroscopic constitutive model for the porous SMA material using the properties of the dense SMA and information about the pore shape and porosity level. Several macroscopic parameters are identified: macroscopic stress, total and transformation strain tensors, as well as the macroscopic elastic stiffness. During the derivation of the model both change in the elastic stiffness and the development of the transformation strain in the SMA are taken into account. Two types of strain concentration factors are defined: instantaneous and elastic, which are calculated using the tangent stiffness of the dense SMA and its elastic stiffness, respectively. The effect of the different terms in the macroscopic constitutive model is investigated and their physical meaning is explained. Comparisons of the modeling results with quasistatic and dynamic experiments are attempted for porous SMAs formed by sintering under pressure powders of Ni and Ti at equatomic composition.

VARIATIONAL FORMULATION AND MATERIAL BALANCE LAWS OF DISSIPATIONLESS THERMOELASTICITY

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ABSTRACT

This work is devoted to the Lagrangian formulation and the derivation of material balance laws of non-linear thermoelasticity of Green and Naghdi, that is, a hyperbolic, dissipation-less thermoelasticity in which disturbances propagate with finite wave speed. The lack of dissipation of this theory allows for a variational formulation of Hamilton type. The obtained variational formulation is used for the application of Noether's theorem to obtain the conservation laws corresponding to the group symmetries of space-time translations, scaling and space rotations. The group of translations in material manifold provides the so-called material momentum or pseudomomentum equation in conservation form, of great importance, for fracture and phase transitions problems. Also, from the obtained conservation laws are treated in such a manner to develop the corresponding non-homogeneous (source) terms, so as to become balance laws. The non-homogeneous terms are nothing else but the material forces or a sort of moments of such forces. Moreover, the exact conditions under which the above mentioned material balance laws hold are rigorously studied.

In this manner we obtain all equations of interest, that is, the balance of linear momentum, the equation of entropy, the balance of canonical momentum, the balance of scalar moment of canonical momentum and the energy equation all in the apparently "dissipationless form". But these equations can be transformed to those of the classical theory of (obviously thermally dissipative) nonlinear elastic conductors. Therefore, a good starting point for a true canonical formulation of dissipative continuum mechanics, that could be developed in the future, is obtained.

All the obtained results are compared with the already existing ones for particular cases and the relationship to the classical theory is established.

THE INFINITE ISOTROPIC WEDGE UNDER LINEARLY DISTRIBUTED LOADING

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ABSTRACT

The stress analysis in a wedge with infinite radius within the classical linear theory of elasticity has been considered by various investigators. Tranter [1] solved the plane elasticity problem of an infinite isotropic wedge by employing the Airy stress function and by using the Mellin transform. Many applications of this technique were made for the solution of particular problems. Benthem [2] and Baker [3] solved an anisotropic wedge, Matczynski [4] studied the discontinuous boundary conditions and Absi and Morando [5] calculated the stresses in some particular cases of loading. Finally Theocaris, Tsamasphyros and Andrianopoulos [6] confronted the problem of the infinite wedge, systematizing the known results.

In the present paper the special case of an infinite isotropic wedge under linearly distributed loading is considered with a variable-separable solution. Starting from the well known problem of the wedge shaped dam [7], we reduce the elastostatic problem of the infinite isotropic wedge under linearly distributed loading on its faces in a self similar problem. It is observed that the geometry of the wedge and the form of the loading are expressed in a separate-variable form. Therefore the stress field of the elastostatic problem is of the form.

$$\sigma_{ij}(r,\theta)=h_{ij}(r)g_{ij}(\theta), \quad i,j-r,\theta \tag{1}$$

Using the equilibrium conditions for forces and moments, the unknown functions $h_{ij}(r)$ and the order of r in the stress field expressions are determined. Selecting appropriate terms from the Michell tables [8], the stress function, the $g_{ij}(\theta)$ functions and the stress field are easily obtained. Finally applying the boundary conditions, the unknown coefficients of the stress field are determined.

The advantages of the proposed solution are:

(i) the use of self-similarity property in the wedge elastostatic problem not only for concentrated loads at the apex but also for distributed loads along the faces.

(ii) the determination of the stress function from the Michell tables according to the self-similarity property.

The proposed solution is applied to the elastostatic problem of a composite isotropic two materials infinite wedge under a linearly distributed loading along the external faces of the wedge (Fig.1). The behavior and the compatibility of the two materials composite wedge is studied for different materials combinations.

References:

[1] Tranter, C.J.: The use of the Mellin transform in finding the stress distribution in an infinite wedge, Quart. Jour. Mech. Appl. Math., **1**, 125 (1948).
[2] Sneddon, I.N., Fourier transforms. P. 439. New York: McGraw-Hill. 1951.
[3] Sternberg, E., Koiter, W.T.: The wedge under a concentrated couple: a paradox in the two-dimensional theory of elasticity, Jour. Appl. Mech., **25**, 575 (1958).
[4] Benthem, J.P.: On the stress distribution in an isotropic infinite wedge. Quart. Appl. Math., **21**, 189 (1965).
[5] Baker, B.R.: Closed forms for the stress in a class of orthotropic wedges. J. Appl. Mech., **26**, 26 (1965).
[6] Theocaris, P.S., G. Tsamasphyros and N. Andrianopoulos: The problem of the infinite wedge, Acta Mechanica, **34**, 63-87 (1999).
[7] Timoshenko, S.P., Goodier, J.N.: Theory of elasticity, Tokyo McGraw-Hill Koya Kusha, Ltd 1970.
[8] Barber, J.R.: Elasticity, Kluwer Academic Publishers, The Netherlands 1992.

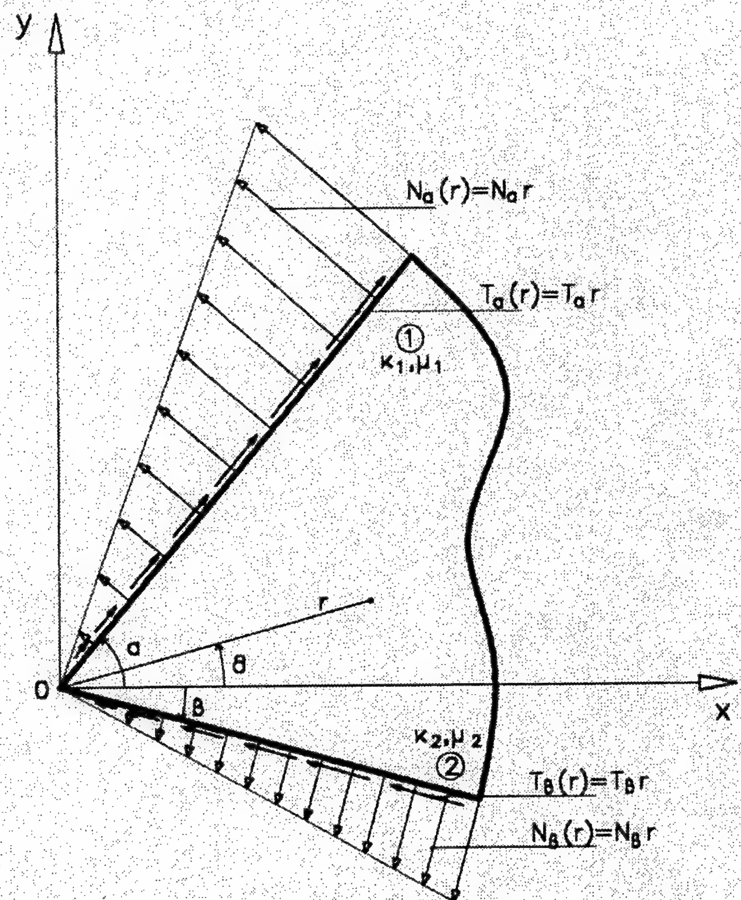

Figure 1. Composite two material wedge under linearly distributed loads on the faces

SIZE EFFECT ON FAILURE LOAD OF MARBLE BEAMS UNDER THREE POINT BENDING

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ABSTRACT

A special gradient-dependent linear beam theory with intrinsic length scales is proposed for the description of the bending behaviour of rock type materials and the study of the size effect, observed experimentally. The problem is considered in two dimensions, and the deformation quan-tities are assumed of infinitesimal order. The elastic strain energy density introduced has the form:

$$w_b = \frac{1}{2}EI\left(\kappa^2 + \frac{1}{\ell_v^2}\gamma^2 + \frac{2}{\ell_s}\kappa\gamma\right) \tag{1}$$

(E is the elasticity modulus, I the second moment of area of the section of the beam and κ the bend-ing curvature). It consists of: (i)The familiar energy term due to the bending moment, i.e. $\kappa^2 EI/2$, and two additional terms i.e. (ii) one accounting for Timoshenko's correction of shear by employing a meso-structural length scale, ℓ_v and (iii) one accounting for surface energy [1] by employing a micromaterial length scale, ℓ_s. The constitutive relation for the bending moment is then derived as:

$$M = (EI)[(1-\alpha^2)\kappa + (1-2\alpha^2)\ell_r\kappa' + \ell_r^2\kappa''], \text{ with } \alpha \equiv \ell_r/\ell_v = \ell_v/\ell_s \text{ and } \ell_r = \ell_v^2/\ell_s \tag{2}$$

The meso-structural length scale ℓ_v is determined directly by the formula for the shear force correction, introduced in Timoshenko's technical beam bending theory [2], while the length ratio α is determined by suitable back analysis of either bending curvature or deflection experimental data.

It is proved, from the analysis that the size dependence of the failure load, P_f, of marble in 3PB, reduced over the respective one predicted by the classical theory, $\overset{o}{P}$, is described by the equation:

$$\frac{P_f}{\overset{o}{P}} \approx \frac{1}{1+4\alpha\sqrt{(1+\nu)/5}(H/L)}\frac{\varepsilon_f}{\varepsilon_{as}}$$

where ε_f is the critical failure strain, ε_{as} its respective asymptotic value, ν is the Poisson's ratio, L the length of the beam and H the height of its rectangular cross section.

According to the present theory the size effect for both the failure load and the failure strain is pronounced in small beam lengths, L, and quickly attenuate inversely proportional to the length to reach the respective values predicted by the classical theory, as it can be seen in Figs.1 and 2.

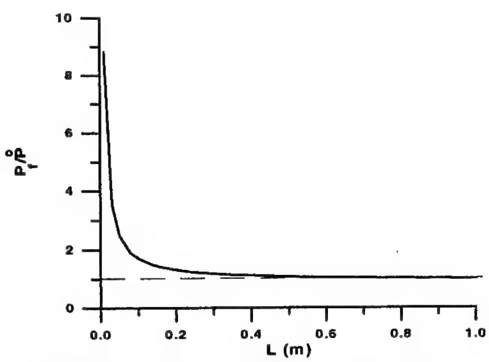

Figure 1: Size dependence of the failure load.

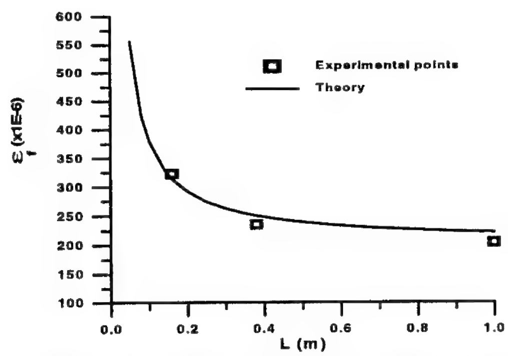

Figure 2. Size dependence of the failure strain.

From Fig.2 it is concluded that the predictions of the present theory conform well with the experimental results, which were obtained from a series of three point bending tests [1].

References:

[1] Exadaktylos, G. E., Vardoulakis, I. & Kourkoulis, S. K. *Int. J. Solids Structures.* In press, 2000.

[2] Timoshenko, S. P. & Goodier, J.N. *Theory of Elasticity.* New York: Mc Graw-Hill, 1970.

FINITE ELEMENT TECHNIQUES FOR GRADIENT ELASTICITY PROBLEMS

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ABSTRACT

Theories with intrinsic or material length scales find applications in the modeling of size-dependent phenomena such as, for example, the localization of plastic flow into shear bands. In gradient-type plasticity theories, length scales are introduced through the coefficients of spatial gradients of one or more internal variables. In elasticity, length scales enter the constitutive equations though the elastic strain energy function, which depends now not only on the strain tensor but on gradients of the rotation and strain tensors as well.

In the present paper, we focus our attention on the strain-gradient elasticity theories developed by Mindlin and co-workers in the 1960's. In such theories, when the problem is formulated in term of displacements, the governing partial differential equation is of fourth order. If traditional finite elements are used for the numerical solution of such problems, then C^1 displacement continuity is required. An alternative "mixed" finite element formulation is developed, in which the displacement and displacement-gradients are used as independent unknowns and their relationship is enforced in an "integral-sense". The resulting finite elements require only C^0 continuity and are simple to formulate. The proposed technique is applied to a number of model problems and comparisons with available exact solutions are made.

THE ELASTIC PUNCH PROBLEM REVISITED

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ABSTRACT

Generalization of elasticity theory by incorporating the effect of higher gradients of the displacement field into the strain energy density function was systematically studied by Cosserat brothers (Cosserat E. and F., 1909), although the main idea can be traced back to the fundamental works of Daniel Bernoulli and Leonard Euler on beam bending. For almost five decades this type of generalization was almost ignored but the question of "oriented medium" or "couple stress theory" reopened in the early 1960's in connection with the theory of defects in continua. A modern systematic treatment of elasticity with gradients was given by Truesdell and Toupin (1960) which was completed later by Mindlin and Tiersten (1962), Mindlin (1964) and Mindlin and Eshel (1968). The common feature of all these studies is that they relate the higher gradients of the displacement field to higher order stresses. In this paper we outline first a procedure for obtaining the relevant influence functions for the Hooke-Casal-Mindlin plane strain half-plane under any distribution of normal (Fig. 1) and tangential loads (Fig. 2) on its bounding surface, in terms of solutions of classical elasticity. This is performed by virtue of complex potentials methods. These functions may be used for boundary element analyses of higher elasticity problems (Exadaktylos, 1999).

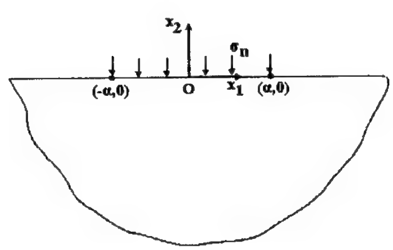

Fig.1. Half-plane under uniform normal load σ_n that is applied over a finite open segment $[-\alpha,\alpha]$ of the bounding edge and choice of coordinates.

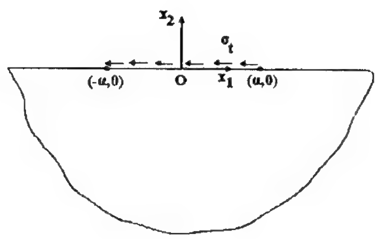

Fig.2. Half-plane under uniform shear load σ_t that is applied over a finite open segment $[-\alpha,\alpha]$ of the bounding edge and choice of coordinates.

We also deal with the half-plane problem under concentrated edge forces and under a uniform distribution of shearing tractions, both of which involve load-induced concentrations of displacement and strain, respectively, and it is illustrated how the proposed higher order elasticity theory can remove these physically undesirable singularities. It is metnioned here that this elimination of the logarithmic singularities on normal and tangential displacements, respectively, has been first performed by Ru and Aifantis (1993) in the frame of Hooke-Mindlin special theory.

Finally, in the frame of the proposed higher elasticity theory we revisit the elastic punch problem illustrated in Fig. 3. It is shown that this mixed-mixed plane strain boundary value problem is reduced to a standard Fredholm integral equation of the second kind that has a unique solution. Further, we give explicit expressions for the stress and strain singularities that arise at the corners of the punch.

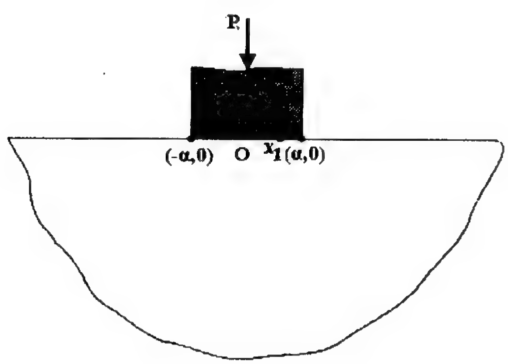

Fig.3. Smooth flat-ended punch.

References:

[1] Casal, P. (1961), La capillarite interne. *Cahier du Groupe Francais d'Etudes de Rheologie C.N.R.S.* VI(3): 31-37.

[2] Cosserat, E. and Cosserat, F. (1909), *Theorie de Corps Deformables,* Paris (A. Hermann, ed.).

[3] Exadaktylos, G. (1999), Some basic half-plane problems of the cohesive elasticity theory with surface energy. *Acta Mechanica* **133**: 175-198.

[4] Mindlin, R.D. and Tiersten, H.F. (1962), Effects of couple-stresses in linear elasticity. *Archs Rations Mech. Analysis* **11**: 415-448.

[5] Mindlin, R.D. (1964), Micro-structure in linear elasticity, *Arch. Rational Mech. Anal.* **16**: 51-78.

[6] Mindlin, R.D. and Eshel, N.N. (1968), On first strain-gradient theories in linear elasticity. *Int.J. Solids Structures* **35**(18): 2251-2281.

[6] Ru, C.Q. and Aifantis, E.C., (1993), A simple approach to solve boundary-value problems in gradient elasticity. Acta Mech., 101: 59.

[7] Truesdell, C. and Toupin, R.A. (1960), *The Classical Field Theories*. Handbuch der Physik, Vol. III/1, Berlin-Gottingen-Heildeberg, Springer Verlag.

GRADIENT ELASTIC BERNOULLI-EULER BEAMS IN BENDING AND BUCKLING

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ABSTRACT

The bending stresses and deformation as well as the critical buckling load of non-classically linear elastic Bernoulli-Euler beams laterally loaded by static loads or axially loaded by compressive axial forces are determined analytically. It is assumed that the bending normal stress is proportional not only to the normal strain but to its second derivative (gradient) with respect to the distance as well. The governing equations of equilibrium and stability in terms of the lateral deflection of the beam are easily derived both by invoking static equilibrium and the corresponding variational principles, which also provide the extra (non-classical) boundary conditions. These conditions are also derived by using the method of weighted residuals. Various boundary value problems are solved analytically and the effect of the gradient term on the response and the critical bulking load is determined by comparing the obtained solutions against the classical ones.

DUAL MODE VIBRATION ISOLATION BASED ON NONLINEAR MODE LOCALIZATION

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ABSTRACT

We consider *dual purpose* nonlinear vibration absorbers that are capable of, (a) isolating the base of the absorber from disturbances generated from machine; and (b) isolating the same machine from disturbances generated at the base of the isolator. To achieve this dual aim we utilize strongly nonlinear stiffness elements that possess no linearized parts. We employ an analytical technique based on complexification and averaging to study the steady state frequency response plots of the nonlinear isolator. This analysis indicates that, if properly designed, the nonlinear isolator possesses stable *localized* steady state periodic motions that confine the energy of vibration either to the machine or close to the base of the isolator. These localized modes enable the fulfillment of the dual vibration isolation aim of the design. We note that the phenomena observed in the systems under consideration are essentially nonlinear, with no analogs in linear systems of similar design. The results pave the way for the design of refined vibration isolation systems of improved performance and effectiveness.

A FRACTIONAL BROWNIAN MOTION MODEL FOR TIME SERIES PRODUCED BY CONSTANT ENERGY MOLECULAR DYNAMICS SIMULATIONS

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ABSTRACT

Molecular dynamics (MD) is a well-established method for simulating materials at the atomic level. The equations of motion are solved at each timestep and one generates successive points of the system in the phase space. During MD simulations several quantities are calculated giving place to quite a number of time series. Time series analysis of several physical properties of systems can provide insight to the behavior of the system.

In the present work we present an analysis of time series of instantaneous temperature and produced during microcanonical (constant energy) temperature molecular dynamics. Simulations were applied to a nickel oxide grain boundary for a temperature range $0.15\text{-}0.80T_m$, T_m being the melting point of the system.

We performed a series of analysis for these time series including test for randomness, power spectrum, Hurst exponent, structure function test and test for turbulence. The obtained results show evidence of fractional Brownian motion. Pressure and temperature time series presents 1/fa noise over the whole range of frequencies of the system. The origins of this observed behavior are discussed. A comparison also is made with results already obtained for constant temperature molecular dynamics where the temperature time series present a two-regime behavior: white noise at low frequencies and $1/f^{\square}$ at high frequencies with a increasing as a function of temperature. The origins of this difference in the behavior are discussed.

VIBRATIONAL PROPERTIES OF A Σ5(310)[001] NiO GRAIN BOUNDARY STUDIED BY MOLECULAR DYNAMICS SIMULATION

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ABSTRACT

Grain boundaries (GBs) have attracted a great interest in ceramics since these materials are often used in polycrystalline form. The reason for this is that many technologically interesting ceramic materials are prepared by powder sintering. GBs may seriously affect several properties such as conductivity, brittle fracture, creep etc. The knowledge of the atomic structure in the boundary region as well as the dynamic properties of the atoms in this region helps understanding such effects. Atomistic simulations are well suited for such studies since they provide a microscopic description of the phenomena. Molecular Dynamics (MD) is one of the most appropriate ones as it can take into account explicitly temperature effects.

In this communication we focus on the study of the vibrational properties of the ions in the GB region by MD simulations. The choice of the material and the boundary lies on the fact that NiO has a relative simple structure and there is earlier work showing the stability of the given boundary. The phonon density of states of the boundary region is calculated at T=300K in the directions parallel and perpendicular to the boundary plane. The obtained results are compared with those for the bulk region and the differences are discussed. We have also calculated the mean square displacements of the ions in the GB region as a function of temperature in the direction perpendicular and parallel to the boundary plane and the results are compared with that of the bulk. The above results lead to some conclusions about the binding of the atoms in the boundary regions.

ANALYTICAL SOLUTION OF THE NONLINEAR DAMPED DUFFING OSCILLATOR

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ABSTRACT

In this paper a systematic study of the Duffing nonlinear equation that describes oscillations with damping is performed. First, the 2^{nd} order non-linear differential equation is transformed into a simpler equivalent Abel equation of the 2^{nd} kind by virtue of appropriate functional transformations. In a second step the Taylor series solution of Abel's equation and the error estimation are given. Finally, the comparison of the numerical solution with the proposed analytical solution for a given initial condition is presented.

NONLINEAR EFFECTS ON THE ELASTIC STABILITY OF A COLUMN-FOOTING SYSTEM ON ELASTIC BASE

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ABSTRACT

A footing with orthogonal resting area is considered, loaded by a vertical load applied eccentrically on one of the axes of symmetry of the resting area. The footing rests on linearly elastic base (Winkler Model). The relation between the eccentricity of the load and the rotation of the footing (rotational stiffness of the elastic base) is derived, with emphasis on the case that the load acts out of the core of the resting area (nonlinear relation-development of neutral portion and working portion).

Then a column-footing system on linearly elastic base is considered, with elastic supports and arbitrary loading at the top of the column. The column joins the footing eccentrically in one of the vertical planes of symmetry of the resting area. The buckling load of the column-footing system is evaluated and found to be different than the Euler critical load of the system. A parametric study is carried out. The effect of the eccentricity of the column and of the applied loading at the top, on the bifurcation of equilibrium of the system is studied.

NON-LINEAR DYNAMIC BEHAVIOUR OF BASE ISOLATORS

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ABSTRACT

The dynamic non-linear behaviour of Lead –Rubber Bearing (LRB) and Friction –Pendulum isolators is investigated. The restoring force of these isolators is modeled using Park model and its extensions Book Wen models. These systems are characterized from abrupt changes in their response and lend themselves to a systematic investigation based on the theory of normal forms. A single mass-isolator system is considered with additional external damping. The free vibration of this system is governed by a second order ODE that depends on the non-dimensionalized hysteretic parameter, which is governed by a first order ODE in time. The two equations are converted into a state space form of three first order ODEs. The system is separated into the linear and non-linear part and a series of transformations are applied to convert it into the simplest possible form, by applying the theory of normal forms. In this form different types of spectral properties are revealed that lead to distinct dynamic behaviour of the one-dimensional isolator. For different sets of initial conditions the phase portraits are presented and their characteristics are discussed.

The restoring forces in the x and y direction of a mass-isolator system is decoupled, whereas the non-dimensionalized hysteretic parameters are governed by a coupled system of ODEs. This often leads to a coupled behaviour in the x and y direction. Following a similar procedure to that of the one-dimensional isolator a system of six first order differential equations is formulated that governs the response of the two-degree of freedom system. The normal forms of this system are determined and an investigation of the different dynamic behaviour is studied based on the spectral properties of its normal forms. For different sets of initial conditions the phase portraits are presented and their characteristics are discussed.

THE CONTINUOUS TIME HOMOGENEOUS MARKOV SYSTEM WITH FIXED SIZE AS A LINEAR ELASTIC CONTINUUM

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ABSTRACT

Every attainable structure of a continuous time homogeneous Markov system (HMS) with n states and fixed size is considered as a point-particle of $\mathbb{R}^n$. Thus, the motion of an attainable structure corresponds to the motion of the respective point-particle in $\mathbb{R}^n$. Under the assumption that "the motion of every particle at every time point is due to its interaction with its surroundings", $\mathbb{R}^n$ becomes a deformable continuum (Tsaklidis, 1998;1999). The evolution of the set of the attainable structures corresponds to the deformation of the continuum. Given the rate of transition probabilities matrix of an HMS with two or thee states, it is examined to what extend the HMS could be regarded as a continuum with elastic material properties. It is then considered that the mechanical behaviour (deformation pattern) of such an elastic body is related to the probabilistic behaviour of the HMS.

References:

1. Tsaklidis, G. (1998). The continuous-time homogeneous Markov system with fixed size as a Newtonian fluid. Applied Stochastic Models and Data Analysis. 13; 177-182.
2. Tsaklidis, G. (1999). The stress tensor and the energy of a continuous-time homogeneous Markov system with fixed size. Journal of Applied Probability. 36; 21-29.

STUDY OF THE DYNAMIC CHARACTERISTICS DURING CALLUS FORMATION

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ABSTRACT

The monitoring of bone fracture healing by non – invasive techniques is crucial in the development of new diagnostic equipment. We propose a theoretical approach to study the dynamic characteristics of a model consisting of the bone diaphysis and a region of callus formation which approximately follows the shape of the bone. The shifting of eigenvalue spectrum proves to be the major indicator in the diagnosis process. The bone diaphysis is assumed to be a finite length hollow piezoelectric cylinder of crystal class 6 while the callus area consists of isotropic, elastic material.

The mathematical description is based on the three-dimensional theory of elasticity and piezoelectricity (in quasi-static approximation). The solution of the wave equation for the piezoelectric cylinder is derived analytically. The solution for the callus area is presented in terms of the Navier vector eigenfunctions for cylindrical coordinates. The boundary conditions at the plane ends of the cylinder are responsible for the selection of the specific solution (odd or even in the z-coordinate) from the general representation. They are emerging from the stabilisation mechanism applied by orthopaedicians (such as external fixators). The lateral surfaces of the isotropic and piezoelectric part are assumed to be free of fields (stress and electric potential), while at the contact surfaces the continuity conditions are met.

The satisfaction of the boundary conditions at the lateral surfaces results into the discretization of the initially continuous range of wave numbers for the isotropic and piezoelectric part. The remaining boundary conditions are satisfied by an orthogonalization procedure which leads to the frequency equation. This is solved through an iterative procedure and the eigenfrequencies of the system are obtained. A parameter analysis is carried out and related results are presented.

ON THE ELECTROENCEPHALOGRAPHY (EEG) PROBLEM FOR THE ELLIPSOIDAL BRAIN MODEL

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ABSTRACT

The present work deals with the development of mathematical techniques, which are directed towards the understanding of the EEG problem for the human brain.

It is well known that the surface of an ellipsoid is the simplest closed surface which takes under consideration the complete anisotropy of the three dimensional space. On the other hand, the ellipsoidal coordinate system is the most general second-degree system in which Laplace's operator separates variables. Therefore, every boundary value problem that involves Laplace's operator in ellipsoidal geometry can be analytically handled. Nevertheless, ellipsoidal harmonics of degree grater than three are not, as yet, known in closed form. One way to deal with such problems is to consider the ellipsoidal surface as a perturbation of a sphere, since corresponding problems in spherical geometry do not suffer from these difficulties. In order to connect the ellipsoidal with the spherical geometry, we first define a spherical coordinate system, with the x-axis, instead of the z-axis, as the polar axis. Such a system exhibits invariance of the spherical harmonics as a consequence of the rotational invariance of Laplace's operator.

The connection of the ellipsoidal with these particular spherical coordinates is then directly obtained through a corresponding passing via the Cartesian system. We use the transformation that we derived to express Laplace's ellipsoidal eigenfunctions as a linear combination of the corresponding spherical ones. Specifically, the sixteen known internal ellipsoidal eigenfunctions are expressed as a finite linear combination of the appropriate internal spherical eigenfunctions. On the other hand, the sixteen known external harmonics involve elliptic integrals and therefore, in order to derive the corresponding expressions, we refer to methods of asymptotic analysis. The reported results are applied to the electric potential, in the interest of reproducing the field due to an electric dipole inside a homogenous ellipsoidal conductor. This potential field is experimentally measurable and provides useful data to the understanding and to the interpretation of the electroencephalographic process.

MATHEMATICAL MODELS FOR BIOMAGNETIC FLUID FLOW AND APPLICATIONS

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ABSTRACT

During last decades an extensive research work has been done on the fluid dynamics of biological fluids in the presence of magnetic field due to the bioengineering and medical applications.

The Biomagnetic Fluid Dynamics (BFD) differs from magnetohydrodynamics (MHD) in that it deals with no electric current and the flow is affected by the magnetization of the fluid in the magnetic field. Besides, BFD require the existence of a spatially varying magnetic field. The field forces arise not from current flow or the presence of free charge but from magnetically polarizable matter subjected to the applied magnetic field.

The purpose of this work is to present: (i) The differential equations governing the biomagnetic fluid flow based on the modified Stokes principles, that is Continuity Equation, Linear and Angular Momentum Equations, Magnetization and Maxwell Equations. (ii) The equations describing the variation of the magnetization of the fluid with temperature or the magnetic field intensity i.e. Langevin Magnetization Equation. (iii) Expressions for the spontaneous and saturation Magnetization M with temperature T less than the Curie temperature T_c. (iv) Simplification and usage of the above-mentioned mathematical models to study the flow of a biomagnetic fluid (blood) under the action of an applied magnetic field for different geometrical boundaries. (v) Solutions of these problems, numerically, and results concerning the velocity and temperature field, skin friction and rate of heat transfer, for different values of the dimensionless parameters entering into the problems under consideration.

The analysis of these results shows that the fluid flow is appreciably influenced by these parameters and especially by those containing the temperature and the intensity of the applied magnetic field. It is hoped that the obtained results can be proved useful for biomedical applications utilizing the knowledge of BFD.

LAMELLAR INHOMOGENEITIES IN PIEZOELECTRIC SOLIDS

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ABSTRACT

We study the problem of a lamellar inhomogeneity of arbitrary shape embedded in a piezoelectric matrix of infinite extent. Uniform asymptotic solutions for the equations of elastostatics and electrostatics on this configuration are obtained. The first order terms, in the inhomogeneity thickness, are explicitly determined for piezoelectric inclusions, rigid inclusions of electric conductor, impermeable cracks and cracks with inside electric field. We give real-form expressions of mechanical and electric fields at the interface and on the inhomogeneity axis. Detailed first order solutions are obtained for elliptic and lemon-shaped inhomogeneities. It is found that, while for elliptic piezoelectric inclusions the perturbation stresses and electric displacements at the inclusion ends have the same order as those given at infinity, for a lemon-shaped inclusion they are an order-of-magnitude smaller. Intensity factors are calculated for lemon-shaped cavities. It is shown that, when inside electric fields are considered, the stress intensity coefficients are influenced by the material anisotropy.

ON A NEW CRACK MODEL FOR PIEZOELECTRIC SOLIDS

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ABSTRACT

We present a mathematical analysis of a new crack model for piezoelectric bodies. In recent years it became evident that the electrically impermeable or the perfect electric contact boundary conditions on the crack faces are inadequate for many physical situations, over- or under-estimating the electric field influence on the propagation process. The crack model here investigated is intermediate between these two limit cases.

The generalized plane problem for an infinite piezoelectric body with a central crack is converted into a system of integro-differential equations. Partial analytic solutions are given so that the system reduces to an integro-differential equation similar to the Prandtl's equation of aerodynamics. For poled ceramics with transversely isotropic symmetry, the integral equation is numerically solved, for both plane and antiplane states of deformation.

The energy release rate are calculated with the discrete solution is then compared with that given by the exact solution for an elliptic hole embedded in the infinite piezoelectric body. A range of values of the cavity thickness is found, for which the considered crack model is a good approximation of the exact two-body problem, while the impermeable and the perfect contact models are not appropriate.

A further stage of the work consists of the study of interface cracks between two dissimilar piezoelectric bodies. This finite crack problem will solved with the same technique and the electric field influence will be estimated in this case.

THERMO-ELECTRO-ELASTIC MATERIAL MOMENTUM EQUATION

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ABSTRACT

This work is devoted to the treatment of pseudomomentum equation in the framework of themo-electro-elasticity. The equations of material momentum for second gradient (both in motion and electric potential fields) materials in electroelasticity and simple materials in thermo-electro-elasticity are derived. The former concerns a non-dissipative process, hence the Lagrangian formulation and Noether's Theorem are used to produce the required equation of material momentum.

The latter, being a dissipative phenomenon due to the thermal terms, is manipulated in another way. Namely, a procedure used by Dascalu and Maugin is applied to obtain the material momentum equation for thermo-electro-elastic materials. It is worth to refer that in the case of second gradient materials in electroelasticity the obtained equation contains - except second gradient elastic terms, as it is expected,- quadrupole terms in polarization.

The results are applied to the problem of a crack propagation in a homogeneous dielectric and thermoelastic body to produce expressions for energy-release rate, a quantity of great importance in engineering applications.

ON THE STOCHASTIC MICROMECHANICAL THEORY OF DISCRETE MATERIAL SYSTEMS

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ABSTRACT

The micromechanical approach has been recognized as a promising tool for the description of the response behaviour of engineering materials with the inclusion of the so-called "*local*" or "*microstructural*" effects. The microstructure of a class of such materials, however, is discrete in the sense of being heterogeneous and/or discontinuous. In view of this fact, deterministic micromechanics, that are based on the concepts of continuum mechanics, could no longer be accepted for the interpretation of the experimental results concerning the behaviour of discrete materials. It has been, therefore, increasingly appreciated that a more appropriate representation of discrete materials would only be achieved by including the random characteristics of the real microstructure. Further, the response behaviour of such microstructure is often both time- and/or loading-history-dependent. Thus, the pertaining deformation process and its space- and time-evolutions are expected to be stochastic in character.

This paper first introduces the basic concepts and postulates pertaining to the stochastic micromechanical theory of discrete material systems. Here, continuum mechanics concepts are generally replaced by considerations of microstructural response variables in the form of discrete statistical functions. Second, the deformation kinematics are presented in the light of the topology of the underlying random microstructure. The latter is established within well-defined "*measuring scales*" defining the levels of observation into the material system. In this context, the establishment of the connection between the response behaviour of the individual elements of the microstructure, their interactions, and the observable macroscopic behaviour would be an essential requirement. The fulfilment of the latter seems possible by the introduction of the principles of set theory, together with the concepts of measure theory. The formulation of the micromechanical behaviour of the discrete system is then attempted via material operators within the scope of a deformation process of a Markov-type which leads to Chapman-Kolmogrov functional presentation.

A CONSTITUTIVE LAW FOR POWDER COMPACTION

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ABSTRACT

A model for powder compaction, which accounts for elastic and power-law creep deformation of the bulk material along with stress-driven diffusion on the interparticle contact areas and curvature-driven diffusion along the pore surfaces, is presented. Important features such as the Laplace relationship between pore surface curvature and normal stress are included in the model. Finite element analysis is used to monitor the time dependent deformation of the powder aggregate under plane strain conditions. Microscopic quantities of interest such as volumetric fluxes, stresses and pore surface curvature are studied in detail. The calculated densification rates of the compact are compared with those predicted by experiment and existing analytical models. Conclusions are drawn on the significance of including the interaction between the densifying mechanisms in powder compaction models. Lastly, a potential is derived from which the overall densification rate of the aggregate can be calculated as a function of the applied stress and porosity.

CONTINUUM MICROPOLAR MODELLING OF DISCONTINUOUS MASONRY-LIKE SYSTEMS

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ABSTRACT

A micropolar continuum equivalent to discrete systems of rigid particles interacting two by two is proposed. This continuum, with local rigid microstructure, can represent the mechanical behaviour of brick/block masonry, as well as jointed rocks or matrix/particle composites, which strongly depends on the shape, the size, the orientation and the arrangement of the units.

In earlier works an integral procedure of equivalence has been adopted to identify the effective moduli of a linear elastic Cosserat continuum. This procedure requires the equivalence of the power expended by a lagrangian systems of interacting blocks and the micropolar continuum in any "corresponding" motions. Even in the elastic frame, the micropolar continuum showed various important features: the possibility of tacking into account the geometry and the texture of the units; the possibility to discern the behaviour of systems made of different size ; the possibility to describe the unsymmetries along different planes. These last two features cannot be described using a classical "simple" continuum. In this work, in order to take into account the low capability to carry tensions and the friction at the interfaces between elements, a non-linear costitutive micopolar model is derived using the power equivalence procedure and defining non-linear constitutive functions for the interactions in the lagrangian system. The non-linear problem is solved through a finite element procedure based on the iterative adjustment of the constitutive tensor due to the occurrence of some limit situation for the contact actions in the discrete model. Various numerical analyses carried out on masonry walls, made of blocks of different arrangement and size, point out the above mentioned essential features and the differences between the classical and the micropolar model, which are amplified in the non-linear frame.

References:

[1] P. Trovalusci, R. Masiani, "Material symmetries of micropolar continua equivalent to lattices", *International Journal of Solids and Structures,* **36**, 1999, 2091-2108.

SOME ASPECTS OF A MICROPOLAR PLASTICITY THEORY

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ABSTRACT

The aim of the paper is to present a theory for finite deformation micropolar plasticity. The theory relies upon the multiplicative decomposition of deformation gradient and the micropolar rotation tensor into elastic and plastic parts, respectively. For the elastic strain and curvature tensors elasticity laws are obtained by considering the second law of thermodynamics in the form of the Clausius-Duhem-inequality. For the plastic parts of the strain and curvature tensors flow rules in form of normality conditions are derived from the postulate of Il'iushin, which is appropriately formulated in order to account for micropolar continua. These normality rules are in terms of a yield function in stress space depending on a stress tensor, which represents a counterpart of the Mandel stress tensor in the classical plasticity.

Kinematic and isotropic hardening are elaborated in the theory by means of corresponding strain and curvature tensors and scalar valued internal variables, respectively. A back stress-couple stress tensor having the structure of a micropolar Mandel stress tensor is defined to describe kinematic hardening in the yield function. The evolution equations for the strain and curvature tensors governing the response of kinematic hardening are derived as sufficient conditions for the validity of the so called internal dissipation inequality. In doing this multiplicative decompositions of the plastic parts of strain and curvature tensors may be introduced, leading to some geometrical interpretations for the variables responsible for kinematic hardening. Additionally, an evolution equation for isotropic hardening is obtained which also provides a sufficient condition for the validity of the dissipation inequality. Characteristic features of this evolution law, is that it depends, beyond the state variables, on the gradient on the yield function. This way, the established micropolar plasticity laws are thermodynamically consistent. Furthermore, it is shown in the paper, how classical plasticity laws may be derived as particular cases of the micropolar plasticity theory proposed.

DESCRIPTION OF PLASTIC ANISOTROPY EFFECTS AT LARGE DEFORMATIONS

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ABSTRACT

A constitutive model for plastic anisotropy is proposed, which employs a set of internal variables describing kinematic, isotropic and orientational hardening. Physically, the mechanical response described may be attributed to materials which obey anisotropic properties from the beginning as e.g. rolled plates, single crystals or materials in structural geology. Also, such constitutive laws may be viewed as the first step towards to describe the material behaviour of polycrystalline materials indicating anisotropy effects of both orientational and distortional type.

Our theory is based on the multiplicative decomposition of the deformation gradient tensor into elastic and plastic parts. The flow rule is obtained as a sufficient condition for the validity of the postulate of Il'iushin in every so called small strain cycle. In particular a normality condition is obtained with respect to a yield function formulated in terms of the Mandel stress tensor. Orientational hardening is incorporated in both the yield and the free energy function, so that orientational hardening effects both the elasticity law and the hardening rule for kinematic hardening. It turns out that the orientational hardening in the elasticity law is essentially described by the flow rule itself. The remaining evolution equations for isotropic and kinematic hardening are assumed as sufficient conditions for the validity of the dissipation inequality. The differential equation governing the response of isotropic hardening is dependent, beyond the state variables, on the gradient on the yield function.

The capabilities of the theory are illustrated for the cases of transverse isotropy and orthotropic anisotropy. Both types of anisotropy are described by means of so called structural tensors. Typical properties are discussed for loading processes with homogeneous and nonhomogeneous deformations. To this end, the constitutive theory has been implemented in the finite element code ABAQUS.

«COLD» WORK AND STABILITY IN SOFTENED MATERIALS

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ABSTRACT

This communication presents the results of two papers submitted for publication in Mechanics Research Communications and International Journal of Engineering Sciences. It is known that the fraction ζ of plastic work, stored as energy of crystal defects and rearrangements and often called «cold» work, is usually taken equal to a constant. The intent of this work is to prove that ζ, assumed to be a function of strain, strain-rate and temperature, can complete the shear stability and instability criteria of softened materials.

Based on recent experimental and theoretical results of P.Rosakis, A.Rosakis, Ravichandran and J.Hodowany, we show that, although the stability and instability criteria between strain hardening, strain-rate sensitivity and thermal softening coefficients are the same with materials with constant cold work, the history of ζ may affect the critical time at which shear banding of power law materials is manifested, as well as the range of values of the stress. Concerning the stability of uniform shearing of a Costin mild steel, it seems that the critical strain γcr at which (ζ,γ) obtains its maximum value, is the leading factor or stable response, together with the hardening capacity of material, while the dependence of ζ on temperature seems to be immaterial during the increasing branch of (ζ,γ) and could affect the stability only after the above critical strain γcr.

SOME BASIC SOLUTION TO DYNAMIC PROBLEMS IN RANDOM MEDIA

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ABSTRACT

In elastodynamics, problems which involve random media, are governed by stochastic differential equations. These equations, under the condition that the differential operator can be decomposed into deterministic plus random parts, can be recast as random integral equations, which are more amenable to numerical treatment. The key component in the aforementioned process is, of course, the existence of suitable Green's functions.

In this work we therefore develop Green's functions for elastic waves in an unbounded random continuum which, in turn, can be used within the contexts of boundary element (BEM) solutions to wave scattering problems of engineering importance. We distinguish two basic cases: First, we have media exhibiting small amounts of randomness, in which case the methodology used is perturbations of all dependent variables about their mean (not necessarily deterministic) solution. Second, we look at media with large randomness, whereby we employ series expansions for the proposed Green's functions, with the basic functions being orthogonal polynomials of random argument (polynomial chaos expansion). The position-dependent coefficients of this expansion can be subsequently computed from a vector wave equation that is uncoupled through use of modal decomposition of the system matrix. Finally, some examples are presented for the simple case of waves radiating from a single source. These results serve to contrast the effect of large versus small randomness. In addition, they help identify the range of applicability of the perturbation method plus the number of terms needed in the polynomial expansion for a desired level of accuracy.

Key Words: Boundary elements; Green's functions; Random media; Wave motions

ANALYSIS OF RAYLEIGH WAVES IN MICROSTRUCTURED SOLIDS BY DIPOLAR GRADIENT ELASTICITY

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ABSTRACT

The present work is concerned with Rayleigh-type surface wave propagation in a material with microstructure. To explain *dispersion phenomena* at high frequencies (small wavelengths) occurring in practical situations, the problem is attacked with a generalized-continuum elasticity theory. This is an effective version of the dipolar gradient theory of Mindlin (1964), and Green and Rivlin (1964). No such a theory was proposed up to now to deal with Rayleigh-wave motions. Similar theories, however, were recently proposed by the authors (see e.g. Vardoulakis and co-workers, 1992; 1995; 1996; 1997; Georgiadis and Vardoulakis, 1998; 2000) and other investigators (see e.g. Fleck et al., 1994; Wei and Hutchinson, 1997) to deal with different wave-propagation and stress-concentration problems.

The classical theory of elasticity predicts no dispersive Rayleigh-wave motions at any frequency, a result that contradicts experimental data. To remedy this shortcoming, dipolar internal forces of collinear type (no couple-stress effects) and higher-order strain and displacement gradients, in both strain and kinetic energies, are considered here in a simple but yet rigorous version of the general Mindlin – Green/Rivlin theory. Both isotropic and anisotropic material response is considered in an effort to model surface phenomena controlling the dispersion of high-frequency surface waves as adequately as possible and to provide means for *estimating* the *micro-mechanical* material parameters involved in gradient theories. Displacement potentials and two-sided Laplace transforms are employed to derive dispersion curves for the high-frequency Rayleigh waves.

The equations followed here that describe the dynamics of *gradient-elastic* (*dipolar* or *grade two* elastic) homogeneous materials *without* couple-stress effects are based on the following expressions for the strain-energy density W and kinetic-energy density T in a 3D continuum (which is composed wholly of unit cells), with respect to a Cartesian coordinate system $Ox_1x_2x_3$

$$W=\frac{1}{2}c_{pqsj}\varepsilon_{pq}\varepsilon_{sj}+\frac{1}{2}d_{pqsj\ell m}\kappa_{pqs}\kappa_{j\ell m}+f_{pqsj\ell}\kappa_{pqs}\varepsilon_{j\ell}\,, \tag{1}$$

$$T=\frac{1}{2}\rho\dot{u}_p\dot{u}_p+\frac{1}{6}\rho h^2\left(\partial_p\dot{u}_q\right)\left(\partial_p\dot{u}_q\right), \tag{2}$$

where $\left(c_{pqsj},d_{pqsj\ell m},f_{pqsj\ell}\right)$ are tensors of material constants, ρ is the mass density, $2h$ is the internal characteristic length of the *structured continuum*, u_p is the displacement vector,

$\varepsilon_{pq}=(1/2)(\partial_p u_q+\partial_q u_p)$ is the usual linear strain tensor with $\partial_p \equiv \partial/\partial x_p, \kappa_{pqs}=\partial_p \varepsilon_{qs}=\partial_p \varepsilon_{sq}$, $(\dot{\ })$ denotes time differentiation, and the Latin indices span the range (1,2,3). Finally, appropriate definitions for the stresses follow from the variation of W

$$\tau_{pq}=\frac{\partial W}{\partial \varepsilon_{pq}}\ ,\quad m_{pqs}=\frac{\partial W}{\partial \kappa_{pqs}}\equiv\frac{\partial W}{\partial(\partial_p \varepsilon_{qs})}\ ,$$

(3a,b)

where τ_{pq} is the (symmetric) Cauchy stress tensor and $m_{pqs}=m_{psq}$ is the double (or dipolar) stress tensor. The latter tensor follows from the notion of *multipolar forces,* which naturally arise from the following expansion of the mechanical power M $M=F_p \dot{u}_p+F_{pq}\left(\partial_p \dot{u}_q\right)+F_{pqs}\left(\partial_p\partial_q \dot{u}_s\right)+\ldots$, where F_p are the usual forces (monopolar forces) within the classical continuum mechanics (monopolar continuum mechanics), and $(F_{pq},F_{pqs},\ldots)$ are referred to as multipolar forces (double forces, triple forces and so on). Thus, the resultant force on an ensemble of particles (material cells) can be viewed as being decomposed into *external* and *internal* forces with the latter ones being self-equilibrating. However, these self-equilibrating forces (which are multipolar forces) produce *non-vanishing* stresses (double stresses, triple stresses and so on), which should be taken into account in a more accurate description of deformed continua than the one provided by classical continuum mechanics.

References:

[1] Fleck, N.A., Muller, G.M., Ashby, M.F., and Hutchinson, J.W., 'Strain gradient plasticity: Theory and experiment', *Acta metall. mater.* 42, 475-487 (1994).

[2] Georgiadis, H.G., and Vardoulakis, I., 'Anti-plane shear Lamb's problem treated by gradient elasticity with surface energy', *Wave Motion* 28, 353-366 (1998).

[3] Georgiadis, H.G., Vardoulakis, I., and Lykotrafitis, G., 'Torsional surface waves in a gradient-elastic half-space', *Wave Motion* 31, 333-348 (2000).

[4] Green, A.E., and Rivlin, R.S., 'Multipolar continuum mechanics', *Arch. Rational Mech. Anal.* 17, 113-147 (1964).

[5] Mindlin, R.D., 'Micro-structure in linear elasticity', *Arch. Rational Mech. Anal.* 16, 51-78 (1964).

[6] Vardoulakis I., and Frantziskonis, G., 'Micro-structure in kinematic-hardening plasticity', *Eur. J. Mech. A/Solids* 11, 467-486 (1992).

[7] Vardoulakis, I., and Sulem, J., *Bifurcation Analysis in Geomechanics*, Blackie Academic and Professional (Chapman and Hall), London (1995).

[8] Vardoulakis, I., Exadaktylos, G., and Aifantis, E., 'Gradient elasticity with surface energy: Mode-III crack problem', *Int. J. Solids Structures* 33, 4531-4559 (1996).

[9] Vardoulakis, I., and Georgiadis, H.G., 'SH surface waves in a homogeneous gradient-elastic half-space with surface energy', *J. Elasticity* 47, 147-165 (1997).

[10] Wei, Y., and Hutchinson, J.W., 'Steady-state crack growth and work of fracture for solids characterized by strain gradient plasticity', *J. Mech. Phys. Solids* 45, 1253-1273 (1997).

THE 3D THERMO-ELASTODYNAMIC PROBLEM OF MOVING LOADS IN A HALF-SPACE

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ABSTRACT

In the present work, an integral transform procedure is developed for obtaining fundamental thermoelastic 3D solutions for thermal and/or mechanical concentrated loads moving steadily over the surface of a half-space. These solutions are *exact* within the bounds of the coupled thermoelastodynamic theory of Biot (1956), and results for surface field quantities (displacements, tangential stresses and temperature) are obtained over the entire speed range (i.e. for subsonic, transonic and supersonic source speeds). The results may serve as Green's functions for *integral-equation* formulations of rapid sliding contacts in the manner indicated by e.g. Barber and Martin-Moran (1982), and Georgiadis and Barber (1993a). The problems considered here are therefore of interest in the areas of contact mechanics, tribology and wave propagation.

The problem is intended to model situations encountered when mating systems are pressed against each other and undergo relative *sliding* motion accompanied by *frictional heating*. Typical cases are: (i) Motion of an asperity developed on the mating surface. Such an asperity may be a material inclusion or some thermomechanical deformation of the mating surface (see e.g. Barber, 1984; Kennedy, 1984; Huang and Ju, 1985), (ii) Brake systems, (iii) High-velocity rocket sleds moving on guide rails (see e.g. Gerstle and Pearsall, 1974), and (iv) Crack face contact in intersonic interfacial rapid fracture of bimaterial plates (see e.g. Lambros and Rosakis, 1995).

Thermoelastic instability and heat checking are often observed in the aforementioned situations (Barber and Ciavarella, 1999), and therefore, a modeling as exact as possible is required to quantify these important effects. Existing analyses, however, commonly use uncoupled thermoelasticity and exclude inertial (dynamic) effects. Also, many of these approaches do not address the case of a mechanical loading and are confined to the 2D case only. On the contrary, the present formulation accounts for both thermal coupling and inertial effects, the importance of which in thermo-elastodynamic problems was revealed by Chadwick (1960) and Francis (1972), among others. In addition, we treat the more general 3D case.

The present study shows generally that a significant rise in the magnitudes of the field quantities occurs in the vicinity of the moving source. Also, the behavior of the various field quantities changes radically when the source velocity crosses a characteristic wave speed and passes into a different range. Our solution technique is based on the use of Radon transforms (see e.g. Deans, 1983) and certain results from distribution theory (see e.g. Gelfand and

Shilov, 1964; Roos, 1969), and also exploits as auxiliary solutions the ones for the corresponding plane-strain thermoelastic and anti-plane shear pure-elastic problems (the latter problems are 2D and uncoupled from each other). This solution technique can also deal with general 3D problems involving: (i) material anisotropy in static and dynamic situations and/or (ii) asymmetry caused by changes in the nature of governing PDEs due to the existence of different velocity regimes (super-Rayleigh, transonic, supersonic) in dynamic situations.

References:

[1] Barber, J.R. (1984) 'Thermoelastic displacements and stresses due to a heat source moving over the surface of a half plane', *ASME Journal of Applied Mechanics* 51, 636-640.

[2] Barber, J.R., and Ciavarella, M. (1999) 'Contact Mechanics', In: *Research Trends in Solid Mechanics* (edited by G.J. Dvorak), Pergamon, New York.

[3] Barber, J.R., and Martin-Moran, C.J. (1982) 'Green's functions for transient thermoelastic contact problems for the half-plane', *Wear* 79, 11-19.

[4] Biot, M.A. (1956) 'Thermoelasticity and irreversible thermodynamics', *Journal of Applied Physics* 27, 240-253.

[5] Chadwick, P. (1960) 'Thermoelasticity: the dynamical theory', In: *Progress in Solid Mechanics,* Vol. 1 (edited by I.N. Sneddon and R. Hill), pp. 263-328, North-Holland, Amsterdam.

[6] Deans, S.R. (1983) *The Radon Transform and Some of Its Applications*, John Willey & Sons, New York.

[7] Francis, P.H. (1972) 'Thermomechanical effects in elastic wave propagation: a survey', *Journal of Sound and Vibration* 21, 181-192.

[8] Gelfand, I.M., and Shilov, G.E. (1964) *Generalized Functions*, Vol. 1, Academic Press, New York.

[9] Georgiadis, H.G., and Barber, J.R. (1993a) 'On the super-Rayleigh/subseismic elastodynamic indentation problem', *Journal of Elasticity* 31, 141-161.

[10] Gerstle, F.P., and Pearsall, G.W. (1974) 'The stress response of an elastic surface to a high-velocity, unlubricated punch', *ASME Journal of Applied Mechanics* 41, 1036-1040.

[11] Huang, J.H., and Ju, F.D. (1985) 'Thermomechanical cracking due to moving frictional loads', *Wear* 102, 81-104.

[12] Kennedy, F.D. (1984) 'Thermal and thermomechanical effects in dry sliding', *Wear* 100, 453-476.

[13] Lambros, J., and Rosakis, A.J. (1995) 'Shear dominated transonic crack growth in a bimaterial - I. Experimental observations', *Journal of the Mechanics and Physics of Solids* 43, 169-188.

[14] Roos, B.W. (1969) *Analytic Functions and Distributions in Physics and Engineering*, John Willey & Sons, New York.

THE ATTITUDE MOTION OF A CARRIER-ROTOR SYSTEM WITH ALMOST SYMMETRIC INERTIA ELLIPSOID, UNDER BODY-FIXED TORQUES

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ABSTRACT

The attitude-motion of the carrier-rotor systems poses an excellent position among the problems which attract the interest of scientists and engineers, particularly of those who deal with Gyro-dynamics and control. Such systems, which are referred to as gyrostats, are used widely in space technology (dual-spin satellites, vehicles with at least one spinning rotor etc.).

The nonlinear form of the motion equations challenge to profound treatment, but unfortunately closed-form solutions are not available. However, in special cases it is possible to find approximate solutions, which prove to be very convenient for the description of motion and very servicable in practical application. Such a case is presented in this paper. It concerns a gyrostat with an almost symmetric inertia ellipsoid and a rotor axis parallel to either its major or minor axis and which moves under the influence of constant body-fixed torques. The former structural condition is met very often in technical applications. The usual reason is the unavoidable human mistakes in materialization of the original design (see for example the unsuccessful thruster alignment, the thruster mismatch etc.). The latter is a choice satisfying special functional needs.

Under these circumstances the desired solution is obtained in a very compact form, whose reliability is tested by comparison to the respective "exact" solution, which is derived by numerical integration. The illustrated example reveals a difference with oscillatory behavior whose amplitude seems to increase at constant rate. At the limit $\delta \rightarrow 0$ the above compact form tends as expected to the expression which applies to the description of motion when the inertia ellipsoid is perfectly symmetric.

In conclusion, one can say that the proposed approximation is qualitatively correct and able to predict, with satisfactory accuracy, the time history of the actual attitude orientation of the gyrostat, when it is acted upon by body-fixed constant torques.

GRADIENT ANISOTROPIC DAMAGE IN MMCS FOR BRIDGING LENGTH SCALES BETWEEN MACROSCOPIC RESPONSE AND MICROSTRUCTURE

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ABSTRACT

This work provides a consistent and systematic framework for the gradient approach in coupled damage-plasticity that enables one to better understand the effects of material inhomogeneity on the macroscopic behavior and the material instabilities. The idea of multiple scale effects is made more general and complete by introducing damage and plasticity internal state variables and the corresponding gradients at both the macro and mesoscale levels. The development of evolution equations for plasticity and damage is treated in a similar mathematical approach and formulation since both address defects such as dislocations for the former and cracks/voids for the later.

Thermodynamically consistent constitutive equations are derived here in order to investigate size effect on the strength of the composite, the strain and damage localization effects on the macroscopic response of the composite, and statistically inhomogeneity of the evolution related damage variables associated with the RVE.

This approach is based on a gradient dependent theory of plasticity and damage over multiple scales that incorporates mesoscale interstate variables and their higher order gradients at both macro and mesoscales. The interaction of the length scales is a paramount factor in understanding and controlling the material defects such as dislocation, voids, and cracks at the mesoscale and interpret it at the macroscale. The behavior of these defects is captured not only individually, but also the interaction between them and their ability to create spatio-temporal patterns under different loading conditions.

TWO SCALE DAMAGE MODEL FOR FATIGUE REPRESENTATION OF GRADIENT EFFECTS

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ABSTRACT

Fatigue is usually modeled by considering the maximum stress versus number of cycles to failure curve, known as the Wöhler curve. This practical approach is uniaxial and may not be relevant when 3D states of stress arise in the structure: how to represent then the mean stress effect? what is the fatigue limit for a complex loading (random and/or non-proportional)?

We present here a two scale damage model built for monotonic loading, low cycle (LCF) as well as high cycle fatigue (HCF). We will only describe in this paper the HCF applications.

Two scales are defined:

- mesoscale : scale of the representative volume element (RVE) of classical continuum mechanics. For HCF, the RVE remains elastic.
- microscale : scale of the micro-defects present in the RVE. At this scale, micro-plasticity and micro-damage occur. Lemaitre and Chaboche damage constitutive equations may be applied.

The inputs of the model are the meso-stress and meso-strain history at the most loaded points of the structure. They are determined by an elastic finite element calculation of the structure. The time integration of the constitutive equations over the whole process up to a critical value of damage gives then the number of cycles to crack initiation.

A key point of the model is the description of the scale transition (from meso-scale to micro-scale). The original model uses Eshelby-Kröner localization law, which is a "local" relationship between the meso-field and the micro-fileds at a Gauss point. We propose a more realistic relationship, using a non-local law: we consider that the micro-fields also depend on the meso-stress and meso-strain gradients in the structure.

Some comments are then given on the representation of the size effect in fatigue.

References

Lemaitre J., Sermage J.P. , Desmorat R., "A two scale damage concept applied to fatigue", International Journal of Fracture, vol. 97, pp. 67-81, 1999.
Desmorat R., "Modélisation et estimation rapide de la plasticité et de l'endommagement", Habilitation à Diriger des Recherches de l'Université Pierre et Marie Curie, 2000

GRADIENT ELASTIC BARS UNDER UNIAXIAL STATIC OR DYNAMIC LOAD

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ABSTRACT

The axial stresses and deformation of straight non-classically linear elastic bars loaded axially by static and dynamic forces are determined analytically. It is assumed that the axial stress is proportional not only to the normal axial strain but to its second derivate (gradient) with respect to the distance as well. The governing equations of equilibrium and motion in terms of the axial displacement of the bar are easily derived both by invoking static and dynamic equilibrium, respectively, and the corresponding variational principles, which also provide the extra (non-classical) boundary conditions. These conditions are also derived by using the method of weighted residuals. Various boundary value problems under static and dynamic conditions are solved analytically and the effect of the gradient term on the response is determined by comparing the obtained solutions against the classical ones.

EVOLUTION OF PERSISTENT SLIP BANDS IN FATIGUED METALS

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ABSTRACT

When metals and alloys are driven far from thermal equilibrium by external constraint, they display pattern forming instabilities associated with the ordering of defect populations. Under cyclic loading the tendency of metals to form ordered structures is even more pronounced and the result is the formation of localized bands of intense deformation with well defined periodicity and amplitude known as persistent slip bands (PSB).

The fact that a regular structure appears above a certain value of the driving force (stress) leads to the modeling of these processes by nonlinear equations of the reaction-diffusion type. In that vein, kinematic models have been proposed to describe the collective behaviour of dislocations by taking into account the motion (diffusion) and nonlinear interaction (annihilation, multiplication, pinning etc) between defects. In general, limited information about the solution of these equations has been obtained analytically and only near the bifurcation point.

In the present work, a different approach is proposed to investigate the formation and evolution of PSBs. A crystal under fatigue is considered as an active medium the properties of which depend on two dislocation species with different spatial dispersion namely, the mobile dislocations (inhibitor) and the immobile dislocations (activator). This allows derivation of analytical expressions for the wavelength of the dislocation arrangements and the dislocation densities far from the bifurcation point.

From the stability analysis follows that the initial pattern near the bifurcation point is metastable and evolves towards a stable one. It is shown that the wavelength of a stable pattern lies between two extreme values λ_{max} and λ_{min}. The quantity λ_{max} determines the maximum allowable wavelength, i.e the wavelength above which the number of bands doubles to reach stability. The quantity λ_{min} determines the minimum allowable wavelength, i.e the wavelegth where the bands lose their stability due to strong interaction between them. As a result the number of bands may decrease by a factor of two.

The mechanisms governing the evolution of PSBs are investigated also numerically using computer simulations with different initial conditions. The obtained results are discussed and compared with available experimental observations. It is shown that the proposed approach describes the basic features observed about PSBs and can contribute towards a better understanding of PSB evolution far from the bifurcation point.

CRACK IDENTIFICATION IN BEAM STRUCTURES

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ABSTRACT

Nondestructive testing using vibration techniques have been of great interest for many years. The reason for this is the necessity to detect easily and at low cost structure failures, situation that appears very often. Several methods for non-destructive testing using vibration techniques have been developed most of them based on natural frequencies and damping measurements. The most common structural defect is the existence of a crack. If the structure is defective, there is a change in stiffness and damping of the structure in the region of the defect. Usually, stiffness decreases and damping increases if the defect appears in the form of a micro-or a macro-crack. Hence it is possible to use natural frequency measurements to detect cracks. The natural frequency method has been extensively studied and applied. The change of the natural frequencies of vibration by itself, however, cannot lead to and accurate prediction of both location and size of the defect since it is independent of the position chosen for the measurement. One needs additional information in order to estimate both location and size of the defect in a reliable way.

In this paper the possibility to use the mechanical impedance of the structure as an additional defect information carrier is investigated. For that purpose, the influence of a transverse surface crack on the mechanical impedance of beams under various boundary conditions is studied both analytically and experimentally.

The local flexibility induced by the presence of the crack is modeled by the appropriate spring and relations linking the change in the mechanical impedance to the location and size of the crack are obtained. It is shown that the mechanical impedance changes substantially due to the presence of the crack. The changes follow definite trends depending upon the location of the crack and consequently the impedance can be used as an additional defect information carrier which complementary with natural frequency changes can be used for crack identification in beam structures.

Based on the results of the present work, an efficient scheme for crack identification in beam structures is proposed. Starting with mechanical impedance measurements the location of the crack can be estimated. Once the location is fixed, the relative size of the crack can be estimated with acceptable accuracy using the changes in natural frequencies.

FRACTALS AND FRACTIONAL CALCULUS IN SOLID MECHANICS

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ABSTRACT

The framework for the mechanics of solids, deformable over fractal subsets, is outlined. While displacements and total energy maintain their canonical physical dimensions, renormalization group theory permits to define anomalous mechanical quantities with fractal dimensions, i.e., the fractal stress $[\sigma^*]$ and the fractal strain $[\varepsilon^*]$. A fundamental relation among the dimensions of these quantities and the Hausdorff dimension of the deformable subset is obtained. New mathematical operators are introduced to handle these quantities. In particular, classical fractional calculus fails to this purpose, whereas the recently proposed local fractional operators appear particularly suitable. The static and kinematic equations for fractal bodies are obtained, and the duality principle is shown to hold. An extension of the Gauss-Green Theorem to fractional operators is proposed, which permits to demonstrate the Principle of Virtual Work for fractal media.

From the definition of the fractal elastic potential, the constitutive linear elastic relation is derived. The physical dimensions of the second derivatives of the elastic potential depend on the anomalous dimensions of both stress and strain. Thereby, the elastic constants undergo positive or negative scaling, depending on the topological character of deformation and stress flux. The direct formulation of elastic equilibrium is derived in terms of the fractional LamŽ operators and of the equivalence equations on the boundary. The variational form of equilibrium is also obtained through minimization of the total potential energy. Finally, discretization of the fractal medium is proposed, in the spirit of the Ritz-Galerkin approach, and a finite element formulation is obtained by means of devil's staircase interpolating splines.

CHARACTERIZATION OF MATERIALS WITH PORES AND INCLUSIONS AT DIVERSE SCALES

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ABSTRACT

The recently developed wavelet-based multiscale process is applied to characterize materials with microstructures in the form of pores and inclusions distributed over a wide range of spatial scales. The variance of the strain field for an approximated one-dimensional deformation problem is examined in detail. It is shown that with respect to crack initiation, there is a strong interplay between the distribution of pores and inclusions. Application to a cast aluminum alloy, where pores are, in general, about two orders of magnitude larger than the silicon particles (inclusions), explain recent experimental reports on crack initiation where the interplay of pores, inclusions, and boundaries is observed, yet not explained on a fundamental basis. The present work extends recent efforts on porous materials and includes the interaction of pores at certain scales with inclusions at other scales presented extensively in relevant papers. A detailed review of multiscaling in materials forms an important component of this paper.

Keywords: Multiscaling, Wavelets, Pores, Inclusions, Fatigue, Fracture

SEMI-ANALYTICAL SOLUTION FOR A 1-D SIMPLIFIED THMPC MODELLING OF A NON-SATURATED SOIL

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ABSTRACT

Introduction. Environmental previsions are of great interest for managing natural hazards such as consequences of underground heat storage facilities or contaminations of soils and/or aquifers by pollutants coming from municipal waste disposals. However these types of complex evolutions are not so easy to model due to the strong couplings existing between physical phenomena.

Many efforts have been made to understand them and to propose theoretical [1], computational [2] and experimental tools able to tackle the complexity and therefore the associated difficulties of such modelling. They are linked to the large number of variables, the complexity of the coupled constitutive relations, the variety of thermodynamic evolutions depending on numerous boundary conditions and physically admissible initial conditions [3].

Up to now these difficulties have been tackled by complex numerical modelling based on a general thermo-hydro-mechanical and physico-chemical (THMPC) approach of heterogeneous media [4]. A successful implementation was achieved using a finite difference approach [5]. However, this implementation was restricted to one-dimension (1D), and delicate numerical problems arise when implementing the theory in a 3-D finite element context. To validate such an implementation, a semi-analytical simplified solution can be of great help.

This paper proposes such a semi-analytical solution for a 1-D simplified case study in a non-saturated soil to be compared, as a first step, to a 1-D finite element solution.

Theoretical background. Within the above conceptual framework it is possible to analyse all the coupled phenomena existing between mass, momentum and energy transfer within and between constituents [6]. In order to control the large number of relations and variables an

automatic programming set-up [7] is used at the different stages of the modelling: defining the whole set of variables, setting the constitutive relations and the possible assumptions, defining the initial state and the boundary conditions, computing the different variables and exploiting the results.

Procedures. The simplified 1-D case study chosen here as a support of a semi-analytical solution is a non-saturated clayey-silt column. Four constituents are present : dry air, water vapour, liquid water, clayey-silt. Assumptions are taken in order to focus the study and the discussion on settlements of the column and phase changes between liquid water and water vapour.

On this basis, the constitutive relations include for each constituent: the mass and momentum balance relations plus the material equilibrium and non-equilibrium relations. The principle of the automatic programming set-up is kept using for each constituent a bijection between variables and equations.

As in the complete numerical process, an iterative time process is still used to obtain the semi-analytical solution of this coupled non-linear system. The strategy consists in solving, constituent after constituent, each equation for its associated variable considering that values of all other necessary variables are estimated at the previous iteration step.

Conclusion. It appears that it is possible to obtain a 1-D semi-analytical solution for a simplified THMPC case study to help controlling and validating more complex numerical THMPC modelling.

References:

[1] J. van Meerveld, M.M. Molenaarm J.M. Huyghe, F.P.T. Baaijens Analytical solution and compression, free swelling and electrical loading of saturated charged porous media, Kluwer Academic publishers (to be published).

[2] A.E. Groen, R. de Borst, S.J.M. van Eekelen. "An elastoplastic model for clay: Formulation and algorithmic aspects", in: Numerical Methods in Geomechanics (eds G.N. Pande, S. Pietruszczak), Balkema, Rotterdam, 411-416, (1995).

[3] M-A. Abellan, P. Jouanna, S. Brocas. *Assessing an inital state in a thermo-plastic and physico-chemical complex situation by a perturbation method*, PLASTICITY'2000, Whistler, Canada, July 17-21, (2000).

[4] P. Jouanna, M-A. Abellan. "A generalized approach to heterogeneous media", *Transport in Porous Media* 25: 351-374, December 1996, ISSN 0169-3913, (1996).

[5] Abellan, M-A. Approche phénoménologique généralisée et modélisation systématique de milieux hétérogènes. Illustration sur un sol non-saturé en évolution thermo-hydro-mécanique et physico-chimique. Tome 1 (Concepts) et Tome 2 (Illustration), Thèse de Doctorat, Université Montpellier II, France, (1994).

[6] M-A. Abellan, P. Jouanna. *Ability of computational methods to predict coupled phenomena not accessible to direct experimentations. A typical example in an*

unsaturated soil, Proceedings of NAFEMS world congress'97 on Design, Simulation and Optimisation, Reliability and Applicability of Computational Methods, Stuttgart, Germany, 9-11 April 1997, ISBN 1 874376 20 4, Vol 1, 311-322, (1997).

[7] P. Jouanna, M-A. Abellan. "*General and automatic programming set-up for thermo-hydro-mechanical and physico-chemical evolutions in heterogeneous media*", in Computer Methods and Advances in Geomechanics, Proceedings of the Ninth International Conference on Computer Methods and Advances in Geomechanics (ICCMAG'97), Wuhan, China, 2-7 November 1997, edited by Jian-Xin Yuan, A.A. Balkema, Rotterdam, Brookfield, ISBN 90 5410 904 1, 1165-70, (1997).

COMPACT, HIGH-POWER, SYNTHETIC JET ACTUATORS FOR FLOW SEPARATION CONTROL

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ABSTRACT

Although strong potential of synthetic jets as flow separation control actuators has been demonstrated in the existing literature, there is a large gap between the synthetic jet actuators (SJA) used in laboratory demonstrations and the SJAs needed in realistic full-scale applications, in terms of compactness, weight, efficiency, control authority and power density. In most cases, the SJAs used in demonstrations are either too large or too weak for realistic applications. In this work, we present the development of compact, high-power synthetic jet actuators for realistic flow separation control applications and demonstrate the developed SJA technology in representative, flow separation control problems, including control of steady separation/stall. The developed actuators are compact enough to fit in the interior of a 14.75" chord, NACA0015 wing, have maximum power of 2.0 HP and can produce (for the tested conditions) exit velocities as high as 70 m/sec. Flow visualization and pressure results for flow separation control were obtained over a 14.75" chord, NACA 0015 wing at angles of attack and free stream velocities as high as 25 degrees and 45 m/s, respectively. In addition to flow separation control data, we also present results corresponding to hot wire measurements performed at the exit of the slot for the characterization of the flowfield generated by these synthetic jet actuators.

LOCALIZED PERIODIC MOTIONS IN SYSTEMS OF COUPLED OSCILLATORS

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ABSTRACT

We consider a one-dimensional chain of discrete nonlinear maps with a weak coupling. We consider solutions of the integrable anticontinuous limit, where one or more "central" oscillators move in resonant non-isolated periodic orbits while the other oscillators are at rest. We prove the continuation of these motions for weak non-zero coupling, determine their initial conditions and stability. We apply the above results and perform numerical investigation, in the case where the uncoupled motion of each oscillator is described by the integrable Suris map.

EFFECT OF THE PARAMETERS ON THE DYNAMIC BEHAVIOR OF A SMALL PARTICLE IN AN ANNULAR DISTRIBUTION OF n-BODIES

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ABSTRACT

The N-body problem is still under investigation and the study of various proposed models is in the front-line of the scientific research. In this contribution we present some of the results obtained by the investigation of a N-body model, called the "ring problem" after its geometric configuration. A mass-less particle moves under the combined gravitational attraction of N primaries, N-1 of which have equal masses and are located on a periphery of a circle, while the Nth primary has a different mass and is located at the center of mass of the system. The system is characterized by two parameters, the number of the peripheral primaries $v=N-1$ and the ratio β of the central mass to a peripheral one. The above general configuration reduces to many known problems of Celestial Dynamics as for example the Copenhagen case of the restricted three-body problem, the restricted five-body problem of Ollongren, the restricted four-body problem by Maranhao and Llibre, the Caledonian problem of Roy and Steves and so on. In this paper we investigate the effect of the mass parameter on the dynamic behavior of the particle and we especial focus our interest on the variation of the simple periodic orbits and their distribution in the phase space for many different configurations of the primaries (v=7, 8, 10, 12 and 16).

RESEARCH AND CHALLENGES OF ENGINEERING MECHANICS AND MATERIALS IN THE TWENTY FIRST CENTURY

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ABSTRACT

Over this past half century, technologies have been the major drivers of the economy, and as well, the National Science Foundation [NSF] has been a major supporter of these technological developments. Accordingly there are three transcendental technologies:

- Microelectronics - Moore's Law: doubling the capabilities every two years for the last 30 years; unlimited scalability; nanotechnology is essential to continue the miniaturization process.
- Information Technology - NSF and DARPA started the Internet revolution about three decades ago; confluence of computing and communications.
- Biotechnology - molecular secrets of life with advanced computational tools as well as advances in biological engineering, biology, chemistry, physics including mechanics and materials.

By promoting research and development at critical points where these technological areas intersect, we can foster major developments in engineering. The mechanics and materials engineering communities will be well served if some specific linkages or alignments are made toward these and other enabling technologies such as nano-mechanics and nano-technologies.

MATERIALS RESEARCH AT THE NATIONAL SCIENCE FOUNDATION AND THE NSF NANOSCALE SCIENCE AND ENGINEERING INITIATIVE

T. Weber

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ABSTRACT

This talk will focus on research in materials funded by the US National Science Foundation. The areas support are in condensed matter physics, polymers, solid state chemistry, ceramics, metallurgy, electronic materials and materials theory. In addition, the talk will discuss NSF's participation in the President's National Nanotechnolgy Initiative and Information Technology Research which supports simulation in materials.

DAMAGE MECHANICS APPLICATION ON REPAIR OF DESTROYED STRUCTURES

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ABSTRACT

In the present paper the way of determination of elastic parameters of the body weakened by elliptical voids is presented. Starting from arbitrary placed single elliptical void in plane sheet, decrease of Young's modulus and Poisson's ratio is obtained. After that, using statistical distribution of voids, the decrease of overall elastic constants is found. In this procedure there are two ways, Taylor and Self-consistent model. In the first method interaction of defects is ignored, while in the second, so-called weak interaction is incorporated. Both methods are applied for small concentration of defects. In the case of large concentration of voids Aifantis' gradient approach can be applied. In the paper it is shown that cracks and circles are special cases of the model derived in this study. Such obtained model is applied for determination of stiffness of steel members of the truss of bridge destroyed during lust war by shrapnel of bombshells. Such calculated stiffness is input for static and dynamic analysis of bridges using FEM. This approach is applied for analysis of The Pivnica Bridge, across The Ibar River, on the railway track Belgrade-Thessaloniki, destroyed during lust war. It is shown that with increasing a damage of members of the bridge the time period of free vibrations is increasing to, while natural frequency is decreasing. For such destroyed and repaired structures special attention should be paid to the problem of fatigue.

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COMPUTATIONAL ASPECTS OF MATERIAL INSTABILITIES

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ABSTRACT

Failure in most engineering materials is preceded by the emergence of narrow zones of intense straining. During this phase of so-called strain localisation, the deformation pattern in a body rather suddenly evolves from relatively smooth into one in which thin zones of highly strained material dominate. In fact, these so-called zones of strain localisation act as a precursor to ultimate fracture and failure. Thus, in order to accurately and properly describe the failure behaviour of materials it is of pivotal importance that the strain localisation phase is modelled in a physically and mathematically correct manner, and that proper numerical tools are utilised to actually solve strain localisation phenomena in boundary value problems.

Until the mid-1980s analyses of localisation phenomena in materials were commonly carried out for standard, rate-independent continuum models. This is sufficient when the principal aim is to determine the behaviour in the pre-localisation regime and some properties at incipient localisation, such as the direction of shear bands in tension tests, and in biaxial and triaxial devices. However, there is a major difficulty in the post-localisation regime, since localisation in standard, rate-independent solids is intimately related to a possible change of the character of the governing set of partial differential equations. In the static case the elliptic character of the set of partial differential equations can be lost, while, on the other hand, in the dynamic case we typically observe a change of a hyperbolic set into an elliptic set. In both cases the rate boundary value problem becomes ill-posed and numerical solutions suffer from spurious mesh sensitivity.

To remedy this problem one must either introduce additional terms in the continuum description which reflect the changes in the micro-structure or one must take into account the inherent viscosity of most engineering materials. The effect is that the governing equations do not change type during the loading process and that the strain gradients are finite. Nevertheless, they are steep and the concentration of strain in a small area can still be referred to as strain localisation.

In fact, strain localisation is but one, albeit the most important, of possible material instability phenomena in solids. In this contribution we shall first categorise the different material instability phenomena using a one-dimensional linear stability analysis. Next, we shall point out a broad framework to mathematically regularise the ill-posed set of equations that arises after the onset of localisation. Broadly speaking, this framework involves the introduction of gradients, either in space or in time, of coupled plasticity-damage theories. In order to keep the formulation transparent, we shall ignore the inherent anisotropic character of plasticity and damage when real microstructural changes develop, such as is the case during strain localisation. Illustrative examples using finite elements will be given.

In the next part of the lecture, the non-homogeneous character of materials at a macroscopic scale will be studied. In particular, the effect of imperfections on the failure mode in softening solids and typical measures of the failure mode such as the limit load or the dissipated energy will be quantified in the framework of the finite element reliability method.

The last part of the lecture is devoted to high resolution numerical techniques to properly capture thin zones of highly strained material. Regarding contemporary numerical techniques we will pay attention to meshless methods, which, through their inherent property of a higher-order continuity are ideally suited for inclusion of high-order spatial gradients in constitutive relations, and to the inclusion of discontinuities or zones with steep strain gradients directly in finite elements using the partition-of-unity concept. We will demonstrate that this concept enables the gradual transition from a (higher-order) continuum description to a genuine discontinuum in a finite element context.

EXPERIMENTAL STUDIES OF PLASTIC INSTABILITIES IN SOLID SOLUTIONS

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ABSTRACT

After a brief review of the classification of plastic instabilities, experimental results on two particular types will be considered, (i) Lüders band propagation and (ii) Portevin-LeChatelier (PLC) effect, in Cu- (and Al-) based solid solutions. The behaviour in single and polycrystals will be compared in observations of band propagation and slip line formation, combining informations on mesoscale with macroscopic measurements of stress and of average as well as local strain (employing a laser scanning technique). The temperature and strain rate ranges of existence of the various types of PLC behaviour will be identified in Cu-5...15at%Al polycrystals. In particular the transition from discontinuous PLC deformation to viscous glide at elevated temperatures will be described. Experiments performed at constant strain rates will be compared with those at constant stress rate. Characteristic quantities of PLC band geometry and propagation rate in dependence of strain, temperature and strain rate will be presented and discussed.

COMBINED MEASUREMENTS OF ACOUSTIC EMISSION AND LASER EXTENSOMETRY DURING PORTEVIN-LE CHATELIER DEFORMATION IN AN Al-Mg ALLOY

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ABSTRACT

In addition to sensitive recording of the load serrations during the Portevin-LeChatelier effect in tensile deformation of Al-1.5wt%Mg polycrystals at room temperature (strain rates between 2.67×10^{-6} and 1.33×10^{-4} s^{-1}), the acoustic emission (AE) signals and the local strains in 20 neighbouring zones of 2 mm width along the specimen length (measured by a special laser scanning extensometry technique) are recorded simultaneously. Strong AE bursts can be differentiated from the total AE signal, both showing characteristic dependences along the stress-strain curve. By correlated evaluation of the measured quantities, the AE signals can be assigned to local deformation events of different kinds. The bursts in the first stage of deformation are connected with a Lüders band propagating continuously along the gauge length, while the bursts with successive strong AE activity (decreasing with increasing strain) occur during discontinuous propagation of type B Portevin-LeChatelier bands. The observations are discussed in terms of a superpostition of both dislocation source activation events and collective breakaway with intensive dislocation multiplication.

TOMOGRAHIC PROFILING OF INTERNAL STRESSES

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ABSTRACT

We have been successful in the development of two new powerful techniques, the Scattered Intensity Tomographic Profiling (SITP) and the Energy Dispersive X-ray Diffraction (EDXRD), to probe internal stresses in inhomogeneous solids. This represents a major breakthrough in the field of nondestructive evaluation of localized and global strains in polycrystalline materials for depths from a few micrometers to a few centimeters.

We measured triaxial residual stress depth profiles, directly and accurately, using synchrotron light source methods. We performed control experiments using cantilever beam specimens, which verified the accuracy of our method. Examples of residual stresses profiles will be presented which include: blank steel specimens, grit blasted steels, the effects of Nanostructured Coatings on steels substrates. The results confirm the expectation of large distributions of compressive and tensile stresses. The correlation of the residual stress profiling to fatigue deformation processes will be also discussed. These findings might explain the different types of failure (crack modes) and the effect of fatigue strain tolerance recently reported for same type of Nanostructured Coatings.

Finally, a new approach to the methodology that could lead to fatigue life prediction of load bearing components will be introduced. The EDXRD mapping of a three-dimensional space distribution of local residual stresses at the crack tip produced by overload and other transient effects, is a promising step toward the success of the Unified Approach (DK, Kmax, Kint) for fatigue life predictions of metallic components.

SERRATED YIELDING AND NONUNIFORM PLASTIC DEFORMATION OF PORTEVIN – LE CHATELIER EFFECT IN COMMERCIAL Al-Mg ALLOYS

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ABSTRACT

At a certain stage of deformation history a macroscopically uniform regime of plastic flow may become unstable against strain localization. From the technical point of view of materials design, plastic instabilities leading to strain localization are most important as they influence the workability, the ductility and the service life of materials. Among the various plastic instabilities that a solid can undergo, the Portevin - Le Chatelier (PLC) effect is the best well-known to metallurgists. It consists in repeated propagation of deformation bands along the sample; this is accompanied by the appearance of abrupt stress drops or steps on the deformation curves.

Through uniaxial tensile tests under condition of constant cross-head speeds, following three orientations with respect to the rolling direction, the mechanical characteristics of discontinuous deformation in A5052 commercial alloys has been investigated in some detail. The amplitude of serrated yielding, the frequency of jerky flow under tensile loading, the strain rate sensitivity and the critical strain for the onset have been investigated experimentally as a function of strain, reloading time, and strain rate at room temperature. Also studied are the influences of structural anisotropy on the nonuniform plastic deformation. Anisotropy results are reported and the most important parameters of nonuniform deformation of the Portevin - Le Chatelier effect are re-examined. It is shown that, except for the case of the critical strain, the structural anisotropy of the rolling texture of these materials doesn't have a substantial influence on the features of the nonuniform plastic flow. These materials present a spatial isotropy with respect to the mechanical behavior. The strain rate sensitivity stays unchanged following different directions of tensile test and seems to reach an average value of saturation as a function of strain, and the critical strain dependence on strain rate for the onset of jerky flow presents an inverse behavior in a large domain of strain rates. It should be noted, however, that the frequency of serrated flow, for different strain rates in the range of type B instabilities, is expressed as a function of strain, not more than 16% of deformation, in the form of a power law. The results mentioned above were found to be in good agreement with the literature data.

TIME SERIES ANALYSIS AND THE DETERMINISTIC STRUCTURE OF THE PLC EFFECT

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ABSTRACT

The nature of the mechanism that produces the PLC effect is studied by analysing a single stress time series observed at a particular strain rate of $3.3/(5\cdot 10^6)$, on Cu-10% Al. The time series looks like a shark-jaw sequence, characterised by successive linear up and down patterns. This particular structure of the time series implies that some form of determinism is present imposing this characteristic evolution of the stress. It is therefore plausible that the time series can be found nonlinear and even chaotic as reported recently using methods based on chaos theory. Moreover, it can easily be distinguished from stochastic time series that do not share this special pattern.

Here, we extend this analysis and investigate whether there is a deterministic mechanism that generates the successive up-down patterns, indicating that there is a longer "memory" in the system underlying the PLC effect at this strain rate. To answer this question, we conducted a statistical test for the null hypothesis that the sequence of the up-down patterns is totally random. We have developed a new algorithm that generates surrogate data that represent this null hypothesis, i.e. time series with the same up-down patterns but at random order. We compared the original data to an ensemble of such surrogate time series using a number of linear and nonlinear statistics (such as autocorrelation, mutual information, Lyapunov exponents and prediction error from nonlinear models). The null hypothesis was rejected with some of the statistics (notably including the autocorrelation) as the statistics were found significantly different for the original and surrogate data. This would suggest that there is a "memory" in the system that generates the up-down patterns and one could follow a deterministic approach to model it. However, we repeated the surrogate data test on time series of random sequences of up-down patterns and in some cases we found similar results as for the original data. This lst finding questions whether there are indeed dependences in the succession of the up-down patterns as if they were generated by a deterministic mechanism.

SOME DYNAMICAL SYSTEM CONSIDERATIONS FOR DISLOCATIONS

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ABSTRACT

We study the dynamical interaction between two parallel dislocations under an external force which depends periodically on time. The system is described by the equations

$$\begin{aligned} \frac{dx_1}{dt} &= -F(x_1 - x_2, 2) + m\frac{\partial F}{\partial x}(x_1, 1) + \varepsilon G(t), \\ \frac{dx_2}{dt} &= F(x_1 - x_2, 2) - m\frac{\partial F}{\partial x}(x_2, 1) - \varepsilon G(t) \end{aligned} \tag{1}$$

where

$$F(x,d) = \frac{x(x^2 - y^2)}{(x^2 + y^2)^2}.$$

The parameter m defines the dipole strength and the term $\varepsilon G(t)$ is the external periodic forcing. In this study we have selected $m = 1$ and $G(t) = \sin t$. Equations (1) are invariant under the transformation $x_1 \to -x_2$, $x_2 \to -x_1$, so that the straight line $x_1 + x_2 = 0$ is an invariant axis of symmetry. We define the 2π-Poincaré map and search the structure of the surface of section in a rectangle around the origin. In the unperturbed case $\varepsilon = 0$ there are six asymptotically stable equlibria and the surface of section is divided in eight domains which correspond to the basins of attraction of these equlibria and the basins of $\pm\infty$. We increase the parameter ε and study the generation of new stable fixed points and the structure of their basins of attraction for values up to $\varepsilon = 5$. All stable fixed points are strong nodes and this fact prevents the intersection of the invariant manifolds and the appearance of chaotic motions. These results are preliminary. A complete treatment on the problem will be presented in reference [1].

References

[1] G. Stagika, S. Ichtiaroglou, I. Groma and E. AIfantis, 2001, in preparation.

THE DISLOCATION MODEL OF LOCAL BEND

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ABSTRACT

The heterogeneity of plastic deformation is actual problem of mechanics. In our work on the basis of the mechanics of deformed solids and theory of dislocations, modeling of local bend is carried out. It is represented in the form of two rows of edge dislocations of opposite sings. The equation for local bend angle is found. The gradient of the angle change can be compared with parameters of twist – bend tensor determined by the electron microscopy. Parameters of the dislocation model of local bend are determined; stress fields generated by local bend within infinite crystal are estimated.

MULTISCALE PLASTICITY: LINKING DISCRETE AND CONTINUUM APPROACHES

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ABSTRACT

A multiscale approach to plasticity problems involves connecting three scales: the atomic scale that governs the core properties of dislocations, the mesoscopic scale, which is concerned with the dislocation microstructures and the continuum approaches that deal with the boundary value problem.

At present, mesoscopic simulations of dislocation dynamics and interactions incorporate what is known about the core properties and give access to the relation between microstructure and hardening in single crystals. They can be used for the fine-tuning of constitutive relations in the case of spatially uniform deformation.

The connection between discrete and continuum approaches has been the object of many theoretical attempts in the recent years. In particular, the strain gradients approaches have been developed in order to model internal length scales governing size effects or strain non-uniformities. As some of these length scales (e.g., the Hall-Petch law or confinement effects) directly stem from the defect properties, they can be dealt with using hybrid simulations. The latter combine a mesoscopic code that replaces the usual constitutive form with a Finite Element code that treats the boundary conditions. Potentially, these methods give access to the treatment of complex materials (polycrystals, polyphased materials) under complex loading conditions. In practice, however, there are still at an early stage of development. The current state of the art will be discussed and illustrated by a few simple examples, with emphasis on size effects.

DISCLINATION-DISLOCATION REACTION KINETICS IN APPLICATION TO DEFORMATION PHENOMENA IN SOLIDS

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ABSTRACT

A reaction kinetic approach for the analysis of instabilities and non-uniformities of plastic deformation, such as those occurring at high strains, in nanocrystalline materials and nanostrcutured thin films, is proposed. The approach is based on the introduction of different kinds of defects: mobile gliding dislocations, low-mobility lattice dislocations in the form of dipole configurations, sessile or climbing dislocations, dislocations in terminated walls (partial disclinations), grain boundary and misfit dislocations. For mobile dislocations and disclinations their contribution to the kinetic process is taken into account by means of diffusion-like terms in the balance equations for defect densities. Mutual reactions between different kinds of defects are included into the analysis as a natural source of non-linearity in the system of interacting defects.

The approach is applied to the investigation of the transition from a dislocation-dominated to dislclination controlled kinetics, i.e. from mainly translational to mainly rotational plastic deformation. The peculiarities of the disclination patterns formed under conditions of active plasticity or under steady-state creep are resolved. Finally, the possibility of the approach applications to the materials with high density of grain boundary junctions and nodes of such junctions (i.e. severe deformed metals or nanocrystalline solids) is demonstrated.

ELASTICITY OF WEDGE DISCLINATIONS IN THIN PLATES: APPLICATION TO ELECTRON MICROSOPY STUDY OF DEFECT STRUCTURE IN DEFORMED CRYSTALS

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ABSTRACT

The solutions of the boundary value problem of linear isotropic elasticity are given for wedge disclinations (linear rotational defects of deformable Solids) in the geometry of thin plates. Disclination lines are assumed to be parallel or perpendicular to the free surfaces of the plate. Elastic fields in the plate interior are constructed by applying the technique of "virtual" surface defects. In this technique the integral equations formulated for the densities of virtual defects and originated from boundary conditions at two traction free plate surfaces, has to be solved. The integral equations are resolved by using the Fourier and Hankel-Bessel integral transforms.

The derived in such manner elastic fields (displacements, strains, and stresses) are used for the analysis of electron microscopy images of disclination defects. Disclinations are generated in crystalline material in the course of plastic deformation. In particular, disclination defect can be observed in the junctions of several grain boundaries. The correct quantitative electron microscopy characterization of disclinations in material structures is important for the development of physical based models of material strength and plasticity. Our calculations of disclination electron microscopy images explore Howie-Whelan two electron beams approach and elastic fields of wedge disclinations in a plate of finite thickness. The Howie-Whelan approach uses the dynamical theory of electron beam diffraction in distorted crystals. The obtained results demonstrate the possibility to extract the disclination parameters (strength and orientation) from the data of experimental observations.

PHASE FIELD METHODS AND DISLOCATIONS

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ABSTRACT

Phase Field methods are extensively used to analyse and predict the large-scale dynamical evolution of alloys that undergo phase transitions (order-disorder transitions or phase separations). The main aspect is to take into account, on top of the short-range "chemical interactions", the long-range forces due to the elastic interactions. These dipole-dipole-like interactions play a major role and govern the microstructures at mesoscopic time and space scales (growth laws, morphology of the different coexisting phases...).

We illustrate the application of the Phase Field approach to different situations. Firt, we present a numerical and analytical study of the growth laws in elastically stressed phase separating systems. We show that, in the coarsening regime, the average domain width and average domain length follow different power laws, 1/4 and 1/2} respectively. As in the classical LSW regime, the dynamics in the late stage is dominated by the Ostwald ripening, but the dominant driving force in no more the interfacial energy reduction, as in system with purely short-range interactions, but the relaxation of the strain energy.

Secondly, we present a general formalism for incorporating dislocations into Phase Field methods. This approach is valid for any 3-dimensional anisotropic elastic media with any dislocation distribution. The method is illustrated through the simulation of the dynamics of a phase separating system in presence of static dislocations. Finally, it is also shown that we can incorporate the dynamics of the dislocations into the same formalism. This extends the applicability of the Phase Field methods to the new area of plastic properties of crystalline solids.

STATISTICAL PROPERTIES OF DISLOCATION ASSEMBLIES IN VIEW OF LINKING DIFFERENT SCALES

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ABSTRACT

The investigation of the dynamic behavior of dislocations attracts growing interest because of its importance for the better understanding of many plastic properties of crystalline materials. In the same time, for describing collective dislocation phenomena, like dislocation patterning, the dislocation system has to be studied in micro-scale. Due to the long range nature of dislocation interaction, however, both the analytical and numerical modeling is difficult.

The aim of the present paper is to demonstrate that for an assembly of parallel dislocations (which is the simplest possible relevant dislocation configuration) the link between the discrete and continuum description can be built up on a rigorous manner, i.e. without *ad hoc* assumptions.

In the first part of the presentation it is shown that by neglecting short range order dislocation-dislocation correlations a self-consistent field model can be derived from the equations of motion of individual dislocations. From the stability analysis of this model a criterion is obtained for the development of ordered dislocation structures.

For taking into account short range order correlations the concept of stochastic dislocation dynamics is presented, which can be considered as an intermediate scale description between the discrete and the continuum models. It allows to introduce about 10^6 dislocations into the simulation area. It is found by this method that under multiple slip condition fractal type dislocation distributions develops which is in agreement with recent experimental results.

MICRO-MACRO TRANSITION FOR COHESIVE GRANULAR MEDIA (MACROSCOPIC MATERIAL BEHAVIOR FROM MICROSCOPIC SIMULATIONS)

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ABSTRACT

A basic question in mechanics and physics is how to bridge the gap between a microscopic model and a macroscopic (continuum) description. The former involves contact forces and deformations, whereas the latter concerns tensorial quantities like the stress or the deformation gradient.

The macroscopic balance equations for mass, momentum and energy can be used for the continuum modeling of the behavior of granular media. In order to close the system of equations, they rely on constitutive relations between the physical quantities, since the microscopic details of a granular material are not directly taken into account on the macro-scale.

The model system, a two-dimensional bi-axial box filled with cohesive, frictionless disks of different sizes, is examined by means of a ``microscopic'' discrete element method (DEM). Using the whole box as representative elementary volume, the stress is examined as a function of the applied strain, and the yield surface is determined from bi-axial compression tests. Other measured macroscopic parameters are the Young modulus, the Poisson ratio, the dilatancy angle, the friction angle, and the cohesion.

MACROSCOPIC MATERIAL PROPERTIES FROM QUASI-STATIC, "MICROSCOPIC" DISCRETE ELEMENT SIMULATIONS (MACROSCOPIC MATERIAL BEHAVIOR FROM MICROSCOPIC SIMULATIONS)

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ABSTRACT

One of the essential questions in the area of granular mechanics is, how to obtain macroscopic tensorial quantities like stress and strain from ``microscopic" quantities like the contact forces in a granular assembly. An averaging strategy is introduced, tested, and used to obtain volume fractions, coordination numbers, and fabric properties. We derive the discrete relation for the stress tensor that allows a straightforward calculation of the mean stress from discrete element simulations and comment on the applicability.

Furthermore, we derive the ``elastic" (reversible) mean displacement gradient, based on a best-fit hypothesis. Different combinations of the tensorial quantities are used to compute some material properties.

Because an essential feature of granular systems are rotations of the independent grains, we apply a Cosserat type description. Therefore we compute quantities like the couple stress and the curvature tensor as well as a combination of them, the ``torque-resistance".

LINKING ATOMISTIC AND CONTINUUM APPROACHES FOR STUDIES OF DISLOCATION CORE PROPERTIES IN FCC METALS AND THE EFFECT OF CHEMISTRY

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ABSTRACT

We have employed a new approach, recently developed, which combines the semidiscrete variational generalized Peierls-Nabarro model with parameters determined by ab intio calculations. The resultant approach allows the study of dislocation properties of fcc metals and the effect of chemistry accurately and expediently. We have studied the dislocation core properties of Al with and without H impurities. The generalized stacking fault (GSF) energy surfaces entering the model are calculated by using first-principles Density Functional Theory (DFT). Various core properties, including the core width, splitting behavior, energetics and Peierls stress for different dislocations have been investigated. The correlation between the core energetics and dislocation character has been explored. Our results reveal a simple relationship between the Peierls stress and the ratio between the core width and the atomic spacing. The dependence of the core properties on the two methods for calculating the GSF energy (DFT vs. EAM) has been examined. The EAM gives gross trends for various dislocation properties but fails to predict the correct finer core structure, which in turn can affect the Peierls fails to predict the correct finer core structure, which in turn can affect the Peierls stress significantly. We find that H not only facilitates dislocation emission from the crack tip but also enhances dislocation mobility dramatically, leading to macroscopically softening of the material ahead of the crack tip. We observe strong binding between H and dislocation cores, with the binding energy depending on dislocation character. This dependence can directly affect the mechanical properties of Al by inhibiting dislocation cross-slip and developing slip planarity.

MODELLING OF LAMINATED COMPOSITE STRUCTURES WITH PIEZOELECTRIC LAYERS

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ABSTRACT

Due to the successful applications of piezoelectric actuators and sensors, piezoelectric components made of laminated plates have received particular attention in recent years. The main idea is that certain kinds of structure enable to adapt to or correct for changing operating condition according to electromechanical loads. Piezoelectric composites are usefully utilised for multi-purpose devices or smart materials and numerous applications have been proposed [1] (for instance, micro-robots, active control of vibrations, micro-pump, control of flexible structures or shape control of large space antennas, etc.).

We propose a new approach to laminated piezoelectric plate based on a refinement of the elastic displacements and electric potential through the thickness co-ordinate of the plate. The model accounts for shearing effects of the "sine" type, which satisfy the boundary conditions on the bottom and top faces of the plate [2]. In order to better account for the fact that different materials are present in composite layers a layerwise approximation for the electric potential is introduced. The electric potential distribution along the thickness of the piezoelectric layer includes a term of quadratic order as well as a "cosine" term due to the shearing effects. The approximation of the electric potential turns out to be particularly efficient for the accuracy of the results. The model thus constructed is, in fact, a compromise between simplicity and efficiency. The approximate equations for the piezoelectric plate are deduced from a generalized variational formulation taking into account the continuity conditions at the layer interfaces by using Lagrange multipliers. A particular attention is devoted to the single piezoelectric plate formulation [3]. In addition to the equations for the generalized stress resultants, equations for the electric charge are also obtained for the plate model. The final system of two-dimensional effective equations for the laminated piezoelectric plate governs the extensional, flexural and shear deformation coupled to the applied and induced electric potentials.

The resolution of different situations is then considered for various type of electromechanical loads (density of applied forces, applied electric potential or electric charges on the bottom and top faces of the plate) for single plate, bi-layered, bimorph and sandwich structures. The results thus obtained for the present plate model are compared to the finite element computation for the identical situations performed on the 3D problems. A good agreement is obtained for the elastic displacements and the electric potential as well as stresses for different slenderness ratio and piezoelectric layers made of PZT ceramics [4].

At last, extensions of the present new approach to laminated piezoelectric plate vibrations are also examined. The resonant and antiresonant frequencies obtained with the present model are also compared to the finite element computation. A quite good accuracy is shown for the first

flexural modes and extensional mode, as well. The performance of the model is discussed and application to passive or active control of structure vibrations is evoked.

References

[1] RAO S.S., SUNAR M. : Piezoelectricity and its use in disturbance sensing and control of flexible structures : A survey, *Appl. Mech. Rev.* **47**, 113-123 (1994).
[2] TOURATIER M. : An efficient standard plate theory, *Int. J. Engng. Sci.* **29**, 901-916 (1991)
[3] FERNANDES A., POUGET J. : Two-dimensional modelling of laminated piezoelectric composites : Analysis and numerical results. *J. of Thin-Walled Struct.* (to be published, 2000)
[4] FERNANDES A., POUGET J. : An accurate modelling of piezoelectric plate - Single-layered plate. *Arch. Appl. Mech.* (to be published, 2000).

INVARIANT RELATIONS IN A BOUSSINESQ TYPE EQUATION

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ABSTRACT

A wide class of P.D.Es have at least three conservation laws that remain invariant for certain solutions of them and especially for solitary wave solutions. These conservation laws can be considered as the energy, the pseudomomentum and the mass integrals of these solutions. We are investigating the invariant relation between the energy, the pseudomomentum and the mass for solitary waves in two Boussinesq type equation that come from the theory of elasticity.

KINK DYNAMICS IN A LONG-RANGE INTERACTION MODEL

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ABSTRACT

This talk proposes a one-dimensional lattice model with long-range interactions which, in the continuum, keeps its nonlocal behaviour. In fact, the long-time evolution of the localized waves is governed by an asymptotic equation of the Benjamin-Ono type and allows the explicit construction of moving kinks on the lattice. The long-range particle interaction coefficients on the lattice are determined by the Benjamin-Ono equation.

MAGNETIC SOLITONS

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ABSTRACT

We study the dynamics of solitons in a Landau-Lifshitz equation describing the magnetization of a three-dimensional ferromagnet with an easy axis anisotropy. We numerically compute the energy dispersion relation and the structure of moving solitons, using a constrained minimization algorithm. We compare the results with those obtained using an approximate form for the moving soliton, valid in the small momentum limit. We also study the interaction and scattering of two solitons, through a numerical simulation of the (3+1)-dimensional equations of motion. We find that the force between two solitons can be either attractive or repulsive depending on their relative internal phase and that in a collision two solitons can form an unstable oscillating loop of magnons.

THE PROPAGATION OF STRAIN WAVES IN MATERIALS WITH MICROSTRUCTURE

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ABSTRACT

A lot of the known experimental data on investigation of dynamic behaviour of granular media and crack-containing (damaged) materials at high speeds of deformation cannot be explained within the scope of the classical mechanics. Complex dynamic behaviour of these materials is conditioned by the existence of intrinsic space-time scales in matter: size of grain, lattice period, relaxation time, etc.[1, 2]. Theoretical description of such media is based on crystal lattice dynamics or on a model of hard micro particles continuum.

On the other hand, it is necessary to measure and check the changes of physical and mechanical characteristics of a material for diagnostics and valuation of suitability. For these purposes it is possible to use acoustic waves. A variety of acoustic waves and their ability to penetrate into the bulk of materials, opaque for optical and electromagnetic waves, make them rather valuable, and sometimes irreplaceable at testing materials. The methods of acoustic diagnostics are based on establishment of correlation between structural characteristics of a material and characteristics of elastic waves. At present, the most commonly used methods for nonlinear acoustic diagnostics are based on measurements of the dependence of elastic wave velocity on external stress or on measurements of wave amplitudes. The experiments are carried out using continuous monochromatic waves (the method is based on the parametric interaction of ultrasonic wave with the field of deformation inside the material) and impact excitation on the Kolsky apparatus. Next examples illustrate the phenomena mentioned above [2, 3].

1. The dynamic force measurement. The effect of non-resonant interaction may be used for the dynamic force measurement. The action of a working machine on the base was considered. The measurement was done as follows: a piece of metal in which a longitudinal ultrasonic monochromatic wave with the frequency of 2 MHz (fluctuations of wave frequency are about 2.5 Hz) is excited between the machine and the base. The phase modulation index of the wave transmitted through the metal is proportional to the integral dynamic force acting on the normal to the base surface. Therefore, the integral dynamic force was determined by measuring the phase modulation index.

2. The spatial nonhomogeneity deformation measurement. If the deformation field in the waveguide element of a machine has a character of the travelling wave with unknown distribution of deformations in the cross-section, the phase modulation index of sounding ultrasonic wave will be related to the distribution of deformations by the integral Fourier relation. In this case it was convenient to use the correlation interval as a characteristic of deformation field distribution. For measuring the correlation interval, the investigated element

of the machine must be sounded repeatedly under different angles. The research described in this paper was made possible in part by the INTAS and by RFBR.

References:

[1] Erofeyev V.I., Potapov A.I., Longitudinal strain waves in nonlinearly elastic media with coupled stresses. Int. J .Non-Linear Mech., 1993, V. 28, pp. 483-489.

[2] Erofeev V.I; Rodyushkin V.M. Observation of the dispersion of elastic waves in a granular composite and a mathematical model for its description. Soviet Physics Acoustics, 1992, 38, No6, :pp. 611-612.

[3] Rodyushkin V.M. Elastic wave interaction as a principle of vibration measurement. Ultrasonics, 1995, V. 33, No. 6, pp. 437-439.

GOVERNING EQUATIONS AND BALANCE LAWS FOR MICROPOLAR CONTINUUM

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ABSTRACT

The classical mechanics of continuum proceeds from the idea that a medium consists of material points having three translational degrees of freedom. The orientational effects which cannot be described by equations of the classic theory of continuum mechanics occur in composites, polymers, liquid crystals and so on [1,2]. In the structural-phenomenological description of such media it is supposed that every physically small volume, over which the averaging of the medium properties is performed, contains discrete material microvolumes (structural elements). The kinematics of oriented medium can be described by two vector fields: a field of particles displacements and by a field of their microrotations.

In this paper it has been shown that the appropriate choice of dynamic variables in the variational approach allows one to construct effectively the nonlinear mathematical models of micropolar media in terms of both Lagrange's and Euler's variables [2, 3]. The variational principle for oriented medium has been formulated, from which the variational equations of dynamics and their integrals of motion have been found. The first set of variational equations describe macromotions (i.e. motions of mass centers of the particles), and the second one describe microrotations of structural elements. Equivalence of the variational equations and local laws of conservation of the energy, momentum and angular momentum in terms of Euler's variables has been proved using an example of liquid crystal. It has been shown that the Ericsen's stress tensor and the molecular field in liquid crystal are defined as partial derivatives of free energy.

To take into account the effect of material microstructure, it is formally possible to include various derivatives from structural vectors into expression for free energy density. There are two difficulties interfering with the construction of multipolar theory of microstructured media. The first one consists in finding the complete system of basic invariants of tensors without which the invariant density of Lagrangian cannot be constructed. Secondly, it is necessary to give a physical interpretation of vectors (or tensors), that are used for definition of material microstructure.
The research described in this paper was made possible in part by the INTAS and RFBR (grant 00-02-15682).

References:

[1] J. Pouget, G.A. Maugin, Nonlinear dynamics of oriented elastic solids. PartI. J. of Elasticy, 1989, v.22, pp.135-155.

[2] Lisin V.B., Potapov A.I., Variational principle in mechanics of liquid crystals. // Int J. Non-Linear Mechanics, 1997, v.32, No1, pp. 55-62.

SPLITING UP OF MULTISTABLE SOLITONS IN SOLIDS

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ABSTRACT

A review of theoretical and experimental investigations of the soliton interactions in overtaking and head-on collisions are given. Using a number of examples and analytical and numerical procedures, the interacting solitons have been shown to behave as particles in integrable systems, preserving their individual nature and only acquiring constant phase shifts under a collision ("elastic" interactions). In nonintegrable systems, nonlinear particle-like waves interact in another manner. In an overtaking collision, they radiate part of their energy in the form of quasi-linear wave trains ("inelastic" interaction). Moreover, in numerical modelling, they were found to split up on the head-on collisions. This situation can also be attributed to the fact that these types of events do not lend themselves to description by the equations for the one-wave approximation, but require full equations of nonlinear dynamics taking into account the waves travelling in both directions. These equations frequently turn out to be non-integrable, with solutions described by solitary waves which are not solitons in the rigorous, mathematical sense.

The strongly nonlinear particle-like waves described by an equation with cubic nonlinearity and anomalous dispersion are studied. Such waves possess some properties which distinguish them from the classical solitons. The analysis of numerical modelling results shows that, on numerous occasions, the localized waves behave like solitons. They propagate, as solitons do, at a constant velocity that depends on the amplitude and are stable with respect to small perturbations. If the wave amplitudes are above a certain threshold value then they will split up on the head-on collisions giving rise to the secondary particle-like waves and a quasi-linear wave train [1, 2] Results of numerical simulation and experimental data on propagation and interaction of nonlinear transverse waves in a thin rubber belt are given.

References:

1. A. I. Potapov, A. I. Vesnitsky, Interaction of solitary waves under head on collisions. Experimental investigation. Wave Motion, 1994, v.19, pp. 29-35,

2. V. V. Kazhaev, A. I. Potapov and N. P. Semerikova, Splitting-up of particle-like waves under head-on collision. Radiophysics and Quantum Electronics, 1995, v 38, No 1-2, pp.67-70,

MODELING THE CRUSHING OF A CELLULAR MATERIAL

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ABSTRACT

Deformation of cellular materials is characterized by a strain softening regime where cells collapse. This is modeled in terms of a local constitutive relation with a strain softening part. Interactions between adjacent cells during cell collapse are taken into account, and it is shown that on macroscopic scale such interactions can be approximated by a second-order gradient term in the constitutive equation. Structural randomness of the cellular material is modeled in terms of a random distribution of the local crushing thresholds. The interplay between local softening, gradient coupling and structural randomness is studied. For small randomness, the stress-strain curves are characterized by a yield point followed by a plateau. In the spatio-temporal domain this behaviour is associated with the nucleation and propagation of a localized 'crushing band'. At larger values of the randomness, one finds a monotonically increasing stress-strain relationship associated with a diffuse crushing mode.

MICROSTRUCTURES AND DEFECTS AT MECHANICALLY STRESSED COMPOUND SEMICONDUCTOR INTERFACES

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ABSTRACT

InP Substrate orientation (100), (110)A, (110)B, (111)A, (111)B, (112)A and (112)B significantly affects phase decomposition and ordering. Through TEM, AFM and photoreflectance investigations, the effect of MBE growth on the above surfaces has been determined. Features related to phase decomposition due to (110)A, (111)B and (112)B surfaces have been identified. Anisotropy in optical transitions in samples grown on (110)A and (110)B InP has been identified through photoreflectance investigations.

HIGH PERFORMANCE NANOSTRUCTURED THERMOELECTRIC MATERIALS WITH IMPROVED TE AND MECHANICAL PROPERTIES

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ABSTRACT

Thermoelectrics (TE) have very attractive features such as small size, simplicity, and reliability. This gives them a unique position for dual electrical generation on one side and cooling/heating on the other side. The state of the art research and development clearly indicates that new generation of TE materials and devices are expected to play an important role in future clean and efficient energy conversion systems. Current TE materials are bedevilled by the drawbacks of high cost and low efficiency. For their use in power generation from low grade energy sources there is a need to improve the materials mechanical properties as well.

A dramatic enhancement of the TE materials can be achieved by nanostructuring, e.g. reducing the particle size to nanometer scale, as well as by molecular engineering of the materials. TE materials nanostructuring leads to a decrease of the thermal conductivity thus enhancing their thermal power as well as improving the materials strength and toughness.

In this presentation, we shall briefly describe novel chemical methods for the fabrication of some nanostructured TE materials; Skutterudites and bismuth telluride, Precursors with controlled compositions and high uniformity were synthesized. The precursor was further processed to produce nanophase thermoelectric materials with grain size in the order of 40 nanometer. The processing and characterisation of these materials shall be presented. A remarkable decrease of the thermal conductivity was obtained for nanostructured skutterudite (a decease by one order of magnitude) as a result of the nanostructuring.

INSTABILITIES IN COUPLED SYSTEMS

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ABSTRACT

"Negative Creep" is a different type of instability than the Cahn-Hilliard (e.g. 1958) spinoidal decomposition one. Spinodal decomposition type of instability is due to the loss of convexity of the Helmholtz free energy, $\psi(\varepsilon,-\theta,-\mu)$ while "negative creep" (negative "elastic moduli") occurs in a regio where Cahn-Hilliard stability holds.

Conditions of "negative creep" have been observed experimentally (e.g., Li, 1988, Girt, etal, 1983) and it constitutes an instability for a mechanical system coupled with chemical and/or thermal phenomena. So coupling may induce instabilities and these conditions are presented here by means of a Hadamard instability analysis of the governing differential equations. Both types of instabilities, "negative creep" and Cahn-Hilliard type are predicted by this approach which provides a unified treatment. We distinguish two kinds of coupling: mechano-chemical and thermo-mechano-chemical coupling.

MECHANICAL PROPERTIES OF CEMENT - CLAY MORTARS CONTAINING METHYL - METHACRYLATE POLYMER

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ABSTRACT

The parameters, which should be taken into account, during the restoration of ancient masonries, are the retaining of a constructional aesthetic, using mortars made of materials compatible with the existing ones and the strengthening of the construction. Taking all the above into consideration, in this work we studied the mechanical and physical properties of mortars, with various mixing proportions. These mortars were made of materials, which usually are employed for the restoration of ancient masonries, in combination with polymeric latex, a new technology product.

THE POTENTIAL OF THE MULTIPLE POROSITY MODEL

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ABSTRACT

The hydraulic behavior and contaminant transport in multiple porosity aquifers are complex processes; subsequently a large number of methods have been proposed for their simulation. In this paper will focus our interest in the multiple porosity model. The multiple porosity equations and numerical methods for their solution are presented. The conditions for the validity of the model analyzed and methods for the determination of the phenomelogical coefficients are presented. Finally potential applications of the model to water management resources problems are presented.

GRADIENT PLASTICITY THEORY AND SIZE EFFECTS IN DEFORMATION AND FAILURE OF THICK-WALLED TUBES

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ABSTRACT

In recent years, the role of higher-order strain gradient in the localization of deformation and fracture has been extensively studied. The paper illustrates the influence of specimen size on the plastic deformation and failure behaviour of a thick-walled plastic tube subjected to high internal stress without change of axial length. A simple form of the gradient modification of the deformation plasticity theory is used, which involves one extra term proportional to the Laplacian $\nabla^2(\cdot)$ of the equivalent plastic strain ε in the yield condition.

The well-known size effect relates to the question of the transferability of mechanical test results of geometrically similar scaled-down structural model to the full-scale structures using similitude laws. It concerns also, the validity of small-scale laboratory type test results and their use as a basis for the computational modeling of large-scale components. The obtained analytical solution in combination with a maximum strain failure criterion is used to interpret: a) the influence of the gradient term, and b) the observed size effect.

SOLUTION OF SPHERICAL LAME PROBLEM WITHIN THE FRAMEWORK OF GRADIENT ELASTICITY

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ABSTRACT

Solution of the spherical Lame problem using the model of Gradient elasticity will be presented here. Stress, strain, displacement and strain energy are fully computed and compared with the classical solution. A general method of solving similar problems in curvilinear coordinates is illustrated. Instead of the use of additional boundary conditions enforced in the forth order gradient elasticity equation, a minimization technique is used in order to determine the actual solution form.

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